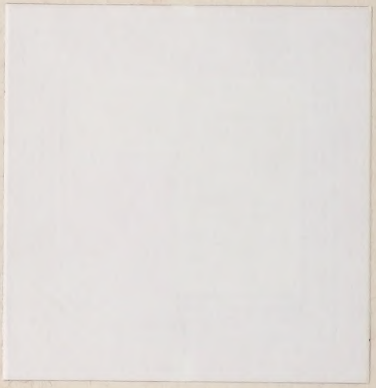


Digitized by the Internet Archive
in 2025 with funding from
Getty Research Institute

https://archive.org/details/textilecolourmix00pate_0

Am

TEXTILE
COLOUR MIXING

Fig. 1.

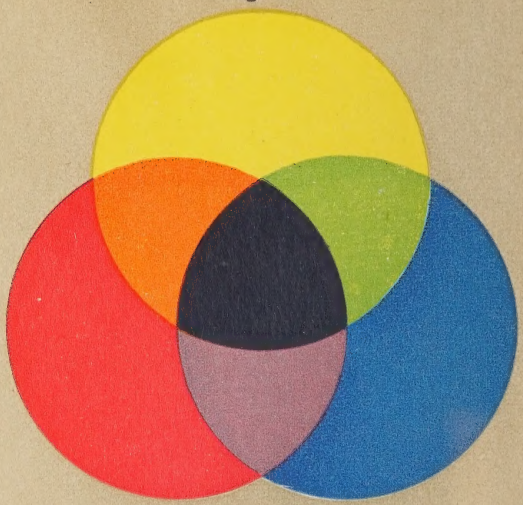
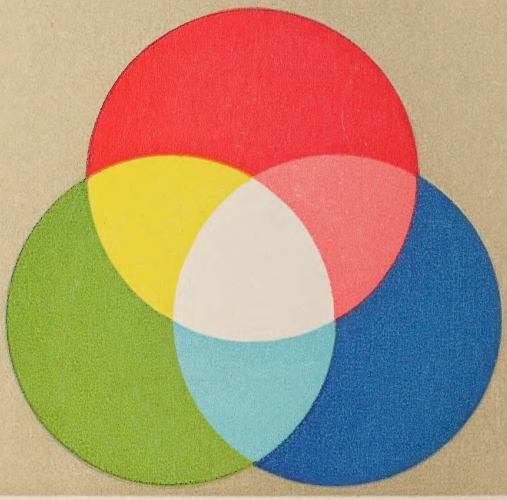


Fig. 2.



Showing Fig. 1: The Subtractive method of mixing colours (Dyes and pigments).
Fig. 2: The Additive method (Coloured Lights).
[*See* Chapter V.]

TEXTILE COLOUR MIXING

A Manual Intended for the Use of Dyers, Calico Printers and Colour Chemists

By DAVID PATERSON
F.R.S.E.

Third Revised Edition

CONS.
SPECIAL
TP
892
P29
1927

LONDON: ERNEST BENN LIMITED
1927

NEW YORK
D. VAN NOSTRAND COMPANY
EIGHT WARREN STREET

Made and Printed in Great Britain by
The Camelot Press Limited,
London and Southampton

THE GETTY CENTER
LIBRARY

PREFACE

TO THE THIRD EDITION

THE call for a third edition of this work has shown to the writer that the simple and practical way in which it was originally written has evidently made its appeal to Textile Colourists.

The same style has been preserved ; but the modern representatives of the old pre-war dyes have been substituted.

It is hoped that, in this revised form, it will meet all the needs of the present-day student.

D. P.

LEEWOOD,
ROSSLYN CASTLE, MIDLOTHIAN.
May 1927.

11/14/29

CONTENTS

Preface . . . . . *page* vii

CHAPTER I

Colour a Sensation—Light Waves—Objects Luminous and Illuminated—Colours of Illuminated Bodies—Production of Colour by Absorption—Diffraction—Dispersion—Fluorescence—Colours of Opaque and Transparent Bodies—Surface Colour . . . . *pages* 1–11

CHAPTER II

Analysis of Light—Spectrum—Homogeneous Colours—Ready Method of Obtaining Spectrum—Simple Absorption Spectra—Aid of Spectroscope . . . . . *pages* 12–19

CHAPTER III

Examination of Solar Spectrum—Dark Lines—Locality of Colours—Spectroscope—Absorption Spectra—Colourists' Use of Spectroscope. *pages* 20–31

CHAPTER IV

Absorption of Colour by Admixture—Absorption Spectra—Solutions and Dyed Fabrics—Luminosity Curves—Absorption Curves—Dichroism—Dichroic Fabrics in Gaslight . . . . . *pages* 32–57

CHAPTER V

Theoretical and Practical Primaries—Mixing by Rotation and Dyeing—Secondary and Tertiary Colours—Constants—Hue, Purity, Brightness—Tints, Shades, Scales, Tones—Sad and Sombre Colours—Complementary Colours . . . . . *pages* 58–83

CHAPTER VI

Colour Mixing—Mixing Qualities of Colours—Pure and Impure Green, Orange and Violet—Variety of Shades from Few Colours—Practical Primaries, Red, Yellow, Blue . . . . . *pages* 84–102

CHAPTER VII

Secondary Colours—Orange—Green—Violet—Nomenclature of Violet and Purple Group—Violet from Pinks and Greens—Purple—Tints and Shades of Violet—Changes in Artificial Light *pages* 103–111

CHAPTER VIII

Tertiary Shades—Broken Hues—Maroons and Browns—Citrines and Olives—Absorption Spectra of Tertiary Shades—Dyed Patterns *pages* 112–128

Index . . . . . *page* 129

APPENDIX

Four Plates with Dyed Specimens Illustrating Text.

LIST OF ILLUSTRATIONS

FIG.		PAGE
1.	Refraction of light by prism	13
2.	Showing homogeneous nature of spectrum colours	14
3.	Simple method of obtaining a spectrum	15
4.	Refraction of light	16
5.	Refracting angle of prism	16
6.	Simple absorption spectra—white, blue, red	18
7.	Solar spectrum showing principal dark lines and the locality of the fundamental colours	21
8.	One-prism spectroscope	23
9.	Two-prism spectroscope	24
10.	Direct-vision spectroscope	25
11.	Absorption spectra of metanil yellow and magenta, dilute and strong	27
12.	Showing green by combining blue and yellow glasses	33
13.	Chromatic circle showing formation of green	34
14.	Absorption spectra showing formation of green	36
15.	Total absorption by combining red and green	37
16.	Absorption spectra showing formation of a compound blue	41
17.	Chromatic circle showing formation of indigo blue	42
18.	Spectrum of ruby glass light	43
19.	Spectrum of dilute magenta light	44
20.	Absorption spectrum of magenta	45
21.	Absorption spectrum of green	46
22.	Absorption spectra of dyestuffs, *i.e.* eosine, azo orange, metanil yellow, malachite green, victoria blue, methyl violet	47
23.	Absorption spectra of chromic chloride	52
24.	Absorption spectra of rhodamine	55
25.	Lambert's method of mixing colours	61
26.	Diagram illustrating Lambert's method	64
27.	Diagrams showing formation of secondary and tertiary colours	77
28.	Simple chromatic circle	79
29.	Chromatic circle showing complementary colours with their tints	81
30.	Chromatic circle showing complementary shades	82
31.	Absorption spectrum of compound red	91
32.	Chromatic circle of magenta and acid yellow	93
33.	Chromatic circle showing formation of a composite blue	101
34.	Absorption spectra of malachite green, methyl violet and composite blue	102
35.	Absorption spectra showing formation of orange and scarlet	105
36.	Absorption spectra of composite violet	109
37.	Absorption spectrum of a maroon	115
38.	Absorption spectrum of a russet	118
39.	Absorption spectrum of a russet composed of orange G and victoria blue	120
40.	Absorption spectrum of olive	121
41.	Absorption spectra of two shades of sage green, of different composition	123

COLOURED PLATES

PLATE

I. *Frontispiece :* Showing mixing of dyes and mixing of coloured lights. PAGE

II. Different results obtained in mixing coloured lights, compared with dyes 63

III. Illustrating suitable and unsuitable colour mixing 84

DYED SPECIMEN PLATES

(*At the end of the book*)

PLATE

I. (1) Carmoisine, WS.
(2) Acid green.
(3) Black.

II. (4) Light sky blue.
(5) Citrine.
(6) Rich brown.

III. (7), (8), (9) Soft greys, light, mid and dark.

IV. (10) Brown.
(11) Sage.

TEXTILE
COLOUR MIXING

TEXTILE COLOUR MIXING.

CHAPTER I

COLOUR A SENSATION—RADIANT ENERGY—OBJECTS LUMINOUS AND ILLUMINATED—COLOURS OF ILLUMINATED BODIES—PRODUCTION OF COLOUR BY ABSORPTION—DIFFRACTION—DISPERSION—FLUORESCENCE—COLOURS OF OPAQUE AND TRANSPARENT BODIES—SURFACE COLOUR.

BEFORE proceeding at once to study the principles which underlie the art of mixing colours and dyes, it may be well to review a few elementary facts in regard to colour itself.

§ 1. **COLOUR A SENSATION.**—The science of colour teaches us that what we call " colour " is merely a sensation, and has no actual existence in the external world. Colour does not form an inherent physical quality of the coloured body. The sensation of colour is produced in a variety of ways, but pre-eminently by the action of light on the retina of the eye.

Everything luminous, from a candle-flame to the sun in the heavens, transmits to the surrounding ether pulses of excessively rapid vibration. These waves of radiant energy are now generally understood to be of an electro-magnetic nature, and travel through space at the inconceivable speed of over 180,000 miles per second.

Clerk Maxwell was the first to predict the relationship between light and electricity. Though these waves of energy all travel at the same speed, the waves are not all of equal length, but are of infinite variety. It is only when these ether vibrations, lying within certain limits, impinge

upon the retina of the eye that the sensation of seeing light and colour is produced.

The wonderful range of electro-magnetic vibrations, extending, on the one hand, from the long billows of the " wireless " vibrations to the excessively minute waves of invisible energy constituting the so-called X-rays and radium rays, constitute something like 62 octaves. That part of this immense keyboard of vibrations which affects the retina of the eye and produces the sensation of light and colour occupies only one octave. In other words, if this vast range of vibrations were spread out to form a ribbon on spectrum of ten feet long, the visible part as we know it, with all its range of colours, from red to violet, would occupy only about two inches of the whole.

But, after all, colour is really independent of light, and the sensation may be produced by other external means. To " see stars " when the eye receives a blow is a common expression for a well-known phenomenon.

If the eyeball be gently pressed with the fingers various different colours are seen, which, as Newton himself described, " resemble the colours of a peacock's tail." As early as 1795, Pfaff, a German physicist, showed that by means of an electric shock on the eyes a series of flashes of light were visible in a totally dark room. The sensation of colour may be produced without external aid, as when a sick person sees certain undefined coloured images floating before the eyes, a fact which, not unusually, gives rise to the idea of seeing ghosts.[1] These few examples show us that what we call **light** and **colour** are merely *sensations* within the eye itself, caused by the visual nerves being stimulated. Colour has really no existence outside of our eye and brain.

[1] Certain drugs too have the power of stimulating the retina so as to produce the sensation of seeing colours where no colours exist.

§ 2. **The Undulatory or Wave Theory of Light** explains most of the many complex phenomena of light, but the subject of colour physics lies beyond the scope of this little manual. The light waves are of different lengths, varying from $\frac{1}{33000}$ of an inch to about $\frac{1}{65000}$ of an inch. The longest undulations which affect the nerves within the retina produce the sensation of red, while the shortest produce the sensation of violet. These light waves may also be indicated by their speed, or frequency of vibrations, the waves producing the sensation of red being the slowest, while the most rapid undulations give rise to the sensation of violet. Vibrations slower and therefore longer than those of the red waves do not affect the eye as light, but are invisible rays of *heat*. Waves that are shorter, or have a "higher frequency," than the extreme violet are also invisible, and are termed the chemical or *actinic rays*. When we speak of light waves of slow frequency we must remember that the term is purely a relative one, as the slowest visible light waves which produce the sensation of seeing red undulate at the inconceivable speed of 392 billion times per second. In other words, when the sensitive retina of the eye receives 392 billions of beats or vibrations per second, there is produced the sensation of seeing the extreme red colour of the spectrum. If the vibrations increase in rapidity to about 760 billions per second, the eye perceives a violet colour. Between these two extremes of wave-speeds there lies an infinite variety of waves of different velocities or wave-lengths, all merging into each other, and producing the sensations of orange, yellow, green, blue, and violet colours. The shorter the wave-length of the colour the farther will it be removed from the red end of the spectrum.

Though there is often a considerable diversity of opinion as to what is actually the typical red or green or blue colour, scientists have been fairly unanimous in selecting the

following colours, with their "frequency of vibration" numbers in billions per second :

Red	392	Green	570
Orange	503	Blue	635
Yellow	517	Violet	740

§ 3. **OBJECTS LUMINOUS AND ILLUMINATED.**—Every object we see is visible either because it gives out light of itself, and is therefore self-luminous, or because it reflects light from its surface. The flame of a candle or a lamp, a glowing piece of coal, or the sun, are simple examples of self-luminous objects which emit streams of luminous rays in all directions. Colours are often described as *luminous* when they reflect a large amount of light to the eye, and are clear and bright.

Illuminated bodies are those which reflect borrowed light to the eye, and the quantity and quality of the reflected light vary with each object. A piece of polished metal and a sheet of glass, for example, when held at the proper angle, will reflect nearly all their incident light ; while a piece of black velvet reflects no light whatever, and gives to the eye the impression of absolute darkness. The less light the object reflects the less visible it becomes. This may be illustrated in a simple manner by allowing a drop of oil to fall on a piece of white paper. By doing so the innumerable little surface reflections of the paper are destroyed, and the surface can no longer reflect to the eye its incident light. Instead of being *reflected*, the light is *transmitted* through the oiled part, and is lost to the eye viewing the surface. This explains the dark grey appearance of an oiled spot on paper. The paper is thereby rendered less *opaque*, and this simple fact forms the basis of the oiled tracing paper or cloth employed by architects and engineers. An experiment the reverse of this may be made with a piece of colourless transparent glass. The light is freely transmitted through the glass ; and, if no ray

of light be reflected from its surface, the glass itself will be invisible. If, however, the glass be crushed to a fine powder, so that innumerable little particles of it reflect the light, then it will present the appearance of a white and almost opaque body.

§ 4. **COLOURS OF ILLUMINATED BODIES.**—When daylight is passed through a glass of perfectly pure water, it will appear absolutely clear and colourless; but if the light be transmitted through a thickness of three or four feet of the same pure water, it will be observed that the light is no longer colourless, but has acquired a decidedly bluish tinge. Some of the rays of light, in passing through the water, have become absorbed or quenched, leaving the bluish-coloured rays to predominate. If, to the glass of pure water, we add a few drops of magenta solution, we will observe the same phenomenon of *absorption*, but intensified in a much greater degree. The white light, in passing through the magenta solution, has become robbed of its bright orange, yellow, yellow-green, and green rays, and the remaining red, blue, and violet-coloured rays combining together in the eye give the sensation of the bluish red or magenta colour. The different quality of the light reflected or transmitted by bodies gives to them their variety of colour. If a substance reflects all the rays of its incident light in equal proportion, it will then appear to the eye of the same colour as the light which illuminates it. Thus, objects which are white by daylight appear yellow by yellow light, green by green light, or red by red light. But, if the object reflects, as in the majority of cases, some rays in larger proportion than others, it will appear coloured, and that colour will consist of the mixture of all the coloured rays which are reflected. We have already seen (§ 2) that white sunlight consists of six principal colours—red, orange, yellow, green, blue, and violet—all marvellously blended together, and

by the admixture of these colours in various proportions is produced all the endless variety and beauty of colour to be found in art and nature. But if the light under which a coloured material is examined be composed solely of one kind of coloured rays, or what is termed a *monochromatic* light, then arises a very different state of matters. The material, no matter how variously coloured it may be in daylight, will reflect only that single colour of its incident light, or none at all. Red, yellow, and blue colours, when examined under a ruby lamp, will be found to lose their bright variety of colour. The red will appear a pale red, the yellow appears a lighter tint of red, while the blue appears a black. The reason why blue appears black in the ruby-red light is, of course, because there are no blue rays in the red light. The blue material, therefore, can reflect no light and must accordingly appear black. A simple and instructive experiment is to take a pattern sheet containing a variety of beautiful dyed colours and view it under a monochromatic yellow light, obtained by sprinkling common salt on the wick of a spirit lamp. It will be seen that, under such a light, colours cannot be distinguished from each other ; reds, blues, pinks, greens, etc., all appear of the same yellowish grey, deepening into black. Such an experiment shows to us that variety of colour depends altogether upon the nature of the incident light, and that the great variety of colours seen in daylight is owing to the great number of differently coloured rays of which the light itself is composed. The slight differences noticed in the appearances of dyed shades, especially the blue and violet class, when viewed under common artificial lights, are due to the same cause, i.e. a deficiency of blue- and violet-coloured rays in the artificial light compared with sunlight. The endless number of hues to be seen in nature arise from the different degrees in which the sunlight is affected.

§ 5. **PRODUCTION OF COLOUR.**—The colours of natural objects are produced, not by one process only, but by several different methods whereby the light is affected. These, with the exception of *absorption*, which is of special interest to dyers and all colourists, will be but briefly noticed here, and, should the student desire further information on these beautiful and interesting phenomena, he is referred to the larger text-books on Colour.

§ 6. **Absorption.**—This is the commonest way in which colour is produced. The colours of dyes, pigments, stained glass, the innumerable hues of flowers, leaves, sea, sky, rocks, etc., are all examples of the selective absorption of certain coloured rays of the sunlight, with the reflection or transmission of others. For example, the blue pigment known as French ultramarine reflects to the eye nearly 40 per cent. of the green-blue, blue, and blue-violet rays; while the remaining rays, consisting of red, orange, and yellow, are absorbed within the pigment. Thus the blue colour of ultramarine is due to its quenching all those rays from red to yellow, and reflecting the remainder, i.e. from green to violet, which combine, within the eye, to give the sensation of an ultramarine blue colour.

Another simple example may be seen in the brilliant pigment emerald-green. This colour is found to reflect to the eye nearly 70 per cent. of the pure yellow-green, green, and blue-green rays of the spectrum, and 25 per cent. of the blue and violet; while the red, orange-red, and orange are completely extinguished.

Likewise the brilliant red colour known as vermilion absorbs all the violet, blue, green-blue, and green rays, leaving only the orange and red rays to the extent of 90 per cent. to be reflected; hence its characteristic *scarlet-red* colour. As this phenomenon of absorption of certain rays, with the reflection of the others, produces the innumerable

hues commonly found in nature, and gives to the artist and the dyer their many varieties of colour, it is by far the most important to the colour mixer, and will accordingly be treated specially in a subsequent chapter.

§ 7. **Diffraction, or Interference.**—This phenomenon depends upon what is termed the *interference* of the waves of light under special circumstances, and gives rise to the most beautiful display of colours. The gorgeous hues of the soap bubble, of tar or oil films upon water, the feathers of the peacock, humming bird, and other foreign birds, the iridescent colours on the wings of beetles, of antique glass, mother-of-pearl, the delicate tints of the opal, etc., are all examples of "interference" or diffraction colours. The beautiful colour combinations seen by viewing crystals in polarised light are examples of the same class.

§ 8. **Dispersion.**—As this property of light gives rise to the most exquisite colours, it forms, like diffraction, a fascinating study for the scientific colourist. In this method of colour production the rays of sunlight undergo neither absorption nor interference, but are simply separated, or dispersed, on account of their different wave-lengths, or what is termed *refrangibility*. The beautiful band of colours known as the spectrum, obtained by passing light through a prism (see Chapter II.), the colours of the rainbow, or the sparkling dewdrop, glowing with emerald and ruby, are all examples of dispersion colours.

§ 9. **Fluorescence.**—Certain substances and liquids, when illuminated with daylight, have the property of emitting a peculiarly coloured light, which, from its first being observed in certain crystals of the mineral fluorspar, is termed fluorescence, a word coined by Stokes in 1852. A piece of uranium or "canary" glass and a solution of sulphate of quinine give respectively a bluish-green and a purplish-blue fluorescent light. Crystals of anthracene show a beautiful violet

fluorescence, while some of the coal-tar colours, such as the eosines, rhodamine, etc., fluoresce an orange or reddish hue. The bluish " bloom " seen on mineral oils is also due to the same property. Resorcine blue and uranin yellow —both aniline colours—are splendid examples of fluorescent substances. An alcoholic solution of chlorophyll, or the green of leaves and plants, shows a claret-red fluorescence. This property is similar to, though not identical with, *phosphorescence*.

§ 10. **COLOURS OF OPAQUE BODIES.**—An opaque body which reflects to the eye from its irregular surface all the rays of incident light in equal proportion, will appear of the same colour as the light which illumines it. Thus a piece of chalk or white paper is white in daylight, yellowish in a yellow artificial light, red in a red light, or green in a green-coloured light. But, in most cases, objects absorb within themselves certain of the rays of light, and reflect the remainder, which combine together, as they enter the eye, to produce what we know as the colour of the object. Vermilion and aniline scarlet, for example, quench or absorb all the coloured rays of the spectrum, except those of the red and orange-red, which are reflected, and these rays give to them their characteristic red colour. If, however, a piece of cloth dyed scarlet, or an object painted with vermilion, be illumined with a green or a blue light, they fail to reflect any blue or green coloured rays, and consequently will appear *black*. Red, scarlet, and orange colours always appear duller and greyer if viewed in the light from a blue sky. The reason why red objects, such as a stick of red sealing-wax, a scarlet poppy, or a soldier's red tunic, appear black when seen in the moonlight or in the dusk, when the evening light is of a very blue quality, is not exactly due to the same cause, but to a visual peculiarity of the colour-perceiving nerves of the eye. The eye does not so readily

appreciate, in a low luminosity, colours belonging to the red end of the spectrum.

Objects which absorb to themselves all the rays of light and reflect none to the eye are therefore devoid of all light or colour, and appear *black* ; and where an equal proportion of rays is uniformly absorbed, and the other reflected, the result is termed *grey*, being intermediate between white and black.

§ 11. **BODY COLOUR.**—If the light penetrates for a short distance into the substance, and is then reflected out again, it will generally appear coloured, if any selective absorption has taken place within the body of the substance. That is, if any of the light rays are absorbed during their passage, the substance will appear coloured by the light which is reflected.

§ 12. **Colour of Transparent Bodies.**—If a transparent substance absorbs certain coloured rays, and transmits others, it will appear coloured from the combination of the transmitted rays.

§ 13. **Surface Colour.**—Other substances reflect certain rays from their surfaces and transmit the remaining rays. Thus, for example, gold reflects from its surface the orange and yellow rays which give to it the characteristic golden colour ; but, if gold be made sufficiently thin—as in gold leaf—to become translucent, it will be found to transmit the bluish-green rays. This phenomenon of *surface* colour, or what is sometimes termed *metallic reflection*, may be observed in many of the coal tar colours, such as magenta crystals, eosine, methyl violet, some aniline greens, blues, and others. Colours of such a nature appear of a different hue according as they are viewed by transmitted or reflected light. Indigo powder, for example, is a blue colour, yet when it is pressed so as to show a polished surface, or when it is crystallised, it gives a coppery reflection. The crystals

of magenta show a dark green reflex like the wings of certain beetles ; while they transmit, when dissolved, a beautiful magenta-red colour. Methyl violet in strong solution reflects a clear, greenish-yellow light. Many aniline greens and blues, such as malachite or benzaldehyde green, victoria green, china green, aniline blue, alkali blue, etc., show a coppery red or a brownish metallic lustre. Although dyers and colourists soon get accustomed to such phenomena, it is nevertheless remarkable that a green crystal should give a *red* solution, and a greenish-yellow substance give a *beautiful violet.* These facts seldom fail to arouse astonishment among those who see the aniline dyes dissolved for the first time. This reflex coloration depends greatly upon the chemical constitution of the colour salt : thus, with the malachite green group the crystallised oxalate salts show a yellow green, or a green lustre ; while the zinc double salts of the same bases show generally a coppery or a red-brown reflex. Metallic reflection colours may be readily seen by making a strong alcoholic solution of these dyes, and allowing a few drops to evaporate on a glass plate. Their reflected and transmitted colours can thus be readily examined. As a rule the colours of the light *transmitted* and of the light *reflected* are complementary to each other ; or, in other words, if the two coloured lights were combined they would again form white light.

CHAPTER II

ANALYSIS OF LIGHT—SPECTRUM—HOMOGENEOUS COLOURS—READY METHOD OF OBTAINING A SPECTRUM—SIMPLE ABSORPTION SPECTRA—AID OF SPECTROSCOPE.

§ 14. If a ray of ordinary sunlight be passed through a prism, the path of the light will be bent or *refracted*, and at the same time the light will be separated or dispersed into a series of the most beautiful colours. This series of colours is called the *spectrum* (a word simply meaning an image or likeness). When carefully examined, the solar spectrum is found to consist of six well-known colours—red, orange, yellow, green, blue, violet. This experiment was first made by Sir Isaac Newton in 1665, who thoroughly investigated the complex nature of light; but, nearly 150 years previous to this, the astronomer Kepler had first demonstrated its compound nature. We have already seen (§ 2) that the longest visible light waves produce the sensation of red; while the shortest or most rapid vibrations produce to our eye the sensation we call violet. Between these two extremes are all degrees of intermediate wave-lengths merging into one another. Thus between the extreme red and the yellow we find many gradual steps, representing bright cherry-red, orange-red, orange, and orange-yellow. Again with a gradual diminution in wave-length the yellow merges into yellow-green, then into a pure green, and from green, by insensible gradations, the light changes to blue, violet-blue, and finally to violet. White light, therefore, is composed of a great number of differently coloured rays, distinguishable from one another by the frequency of their

vibrations, or, in other words, by the length of their waves. With the aid of the prism these rays of light of different wave-lengths are separated or "dispersed," and spread out in the spectrum in a beautiful series of colours, all arranged according to their respective wave-lengths. The following illustration (Fig. 1) shows how, with an inexpensive glass prism, we might perform Newton's famous experiment for

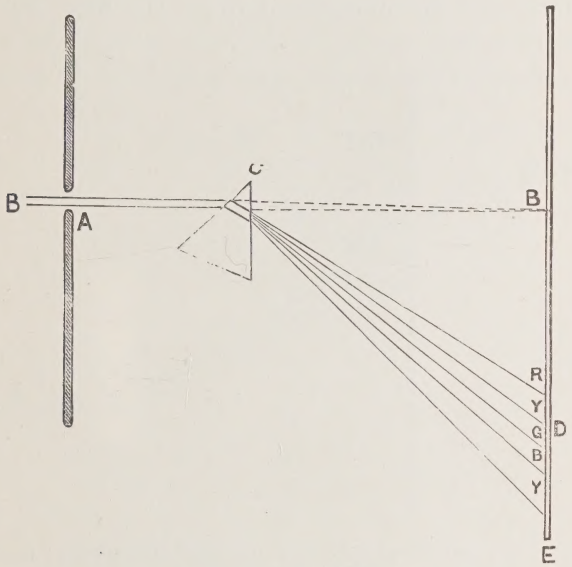


FIG. 1.—Showing refraction of light and production of spectrum by means of the prism.

ourselves. A represents a slit whereby the light is admitted into a dark room. The beam of light (B), in passing through the glass prism (C), is bent out of its course or refracted, and, in being so, is analysed into its various component rays forming the spectrum (D), which can be received on a white screen (E). If we begin at the top of the spectrum nearest the spot B, which represents the direction the beam

of light would have taken had it not been refracted by the prism, we find that the first colour is red, then orange, yellow, green, blue, while the light most refracted is violet.

§ 15. What is termed the *refrangibility* of a colour is the extent to which the colour is refracted or bent in its passage through the prism. Red and orange are described as colours of "*low* refrangibility," while colours of "*high* refrangibility," or those "belonging to the more refrangible end of the spectrum," are understood to be the blue and violet class.

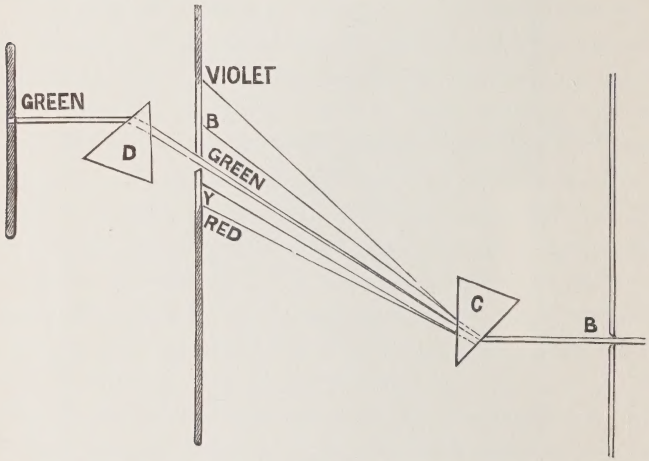


FIG. 2.—Showing homogeneous nature of spectrum colours : green not further decomposed.

§ 16. The colours of the spectrum consist of unmixed or homogeneous lights, and they cannot be further decomposed into any other colours. Thus, for example, the green or the violet rays of the spectrum, when passed through another prism, undergo refraction as usual, but they are not decomposed into yellow and blue for the green or red and blue for the violet, as we might have imagined. They remain the same colours, showing that they are pure and unmixed.

The various hues seen in everyday life—the dyes and pigments and the colours of flowers, etc.—are never homogeneous, but are mixtures of many differently coloured rays. The foregoing diagram, Fig. 2, shows how the purity of spectrum colours may be shown. The spectrum is thrown upon a cardboard screen similar to that in Fig. 1, and a hole is pierced at the desired part of the spectrum—say, in the green—to allow the green rays to pass through a second prism (D), when it will be observed that, though the coloured ray is again refracted, no other colour is separated. But, when we come to analyse the apparently pure colours

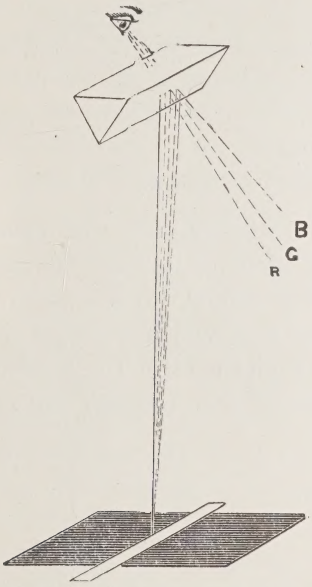


FIG. 3.—Simple method of obtaining a spectrum.

of dyes and pigments, we find that they are often very far from being pure, and contain a large number of other coloured rays. No dye or coloured pigment is known to be perfectly homogeneous in its coloured light.

§ 17. The readiest method of obtaining a spectrum for studying colour is by viewing with the prism a well-illuminated strip of white paper placed on a dark ground—say, a piece of black velvet material. Fig. 3 illustrates how this is best arranged. The refracting angle of the prism should always be held parallel to the object examined. The dotted lines converging to the eye represent the direction of the rays emerging from the prism, and indicate the locality

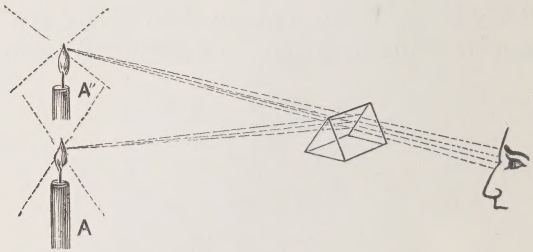


Fig. 4.—Refraction of light.

where the spectrum will appear to the observer. The white strip of paper, on viewing through the prism, will appear coloured the various colours of the spectrum—red, green, and blue. As the rays which traverse a prism are bent, or refracted away from the refracting angle, as seen in Fig. 4, the object A when viewed through the prism will appear

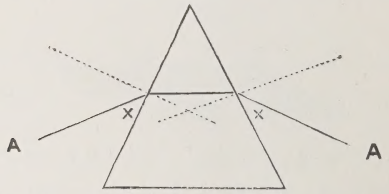


Fig. 5.—Refracting angle of prism.

more in the direction of the angle than is really the case, and will appear at the point A″ as shown in the diagram.

In practice it is always considered best to adjust the prism so that the path of the ray of light (A) makes equal angles with the two sides at which refraction occurs, as shown in Fig. 5.

§ 18. If we place a *blue* strip of paper in a line with the white one, and examine them both together in the same manner, we will find the two spectra side by side are not alike.

In the spectrum of the blue will be seen little or no red, orange, and yellow rays corresponding to those present in the spectrum of white; while the green, blue, and violet rays are similar to that of the white strip, and in exactly the same position. The red, orange, and yellow rays have been quenched or *absorbed* by the blue colouring matter, and, as only the green, blue, and violet rays are reflected to the eye, the result of their combination gives the sensation of a *blue* colour. In Fig. 6 (1 and 2) we have a representation of how the spectra of white and blue differ from each other. The shaded parts in the spectrum of No. 2 (the blue) show where the coloured rays are absorbed, and the *un*shaded parts show where the colours are reflected.

Take again a strip of paper dyed *red*, and examine it with the prism in the same manner. We find that its spectrum, No. 3, is an exact contrast to that of the blue, No. 2. All the bright colours at the red end of the spectrum—i.e. red, orange, yellow—are present, while the green, blue, and violet rays are absent, having been absorbed by the red colouring matter. See No. 3, Fig. 6.

We have considered three simple examples of spectra, and each differing in composition. Examples 2 and 3, where certain coloured rays of the spectrum are absent or absorbed, are termed *absorption spectra*, and the study of such spectra is of invaluable assistance to the colourist in determining the optical nature of all the colours, pigments,

dyes with which he works. Here, then, we have an example of a colour being produced by the quenching of certain parts of the solar spectrum, while the remaining coloured rays combined together to produce the characteristic colour of the substance. These two examples of blue and red colours are of the simplest nature possible ; but the spectra of many colouring matters are often of a complex nature, as may be seen in Chapter VI. It will be observed that the colour present in the absorption spectrum is always in identically the same position as in the spectrum of white light, but not of the same brightness. If, instead of viewing red and blue,

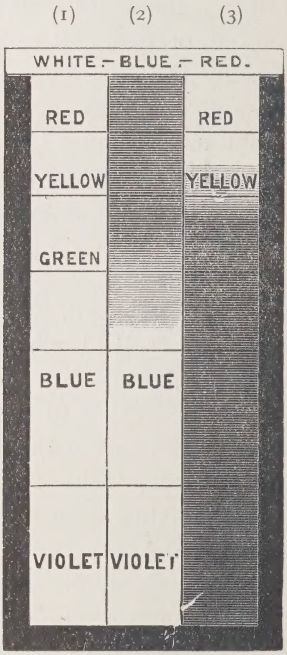


FIG. 6.—Simple absorption spectra. (1) White light. (2) Blue. (3) Red.

we take any other colour, such as green, yellow, violet, olive, or russet, we shall find that *absorption bands* are always

present. Many coloured pigments and dyestuffs have their own peculiar and characteristic absorption spectra (see Fig. 22).

§ 19. These simple experiments with the prism are most interesting and instructive to the colour student. But it would be a difficult matter to locate, with any degree of accuracy, the precise spot on the spectrum where yellow merges into green, or green gradually changes into a pure blue, as all the colours blend with infinite gradations into each other. It would, therefore, be a difficult and unsatisfactory task to try and separate the various colours, and to specify their exact positions on the spectrum, had there not been discovered a remarkable feature in the solar spectrum which enables us to locate with the greatest accuracy any of the colours. It is here that the valuable aid of the spectroscope comes in. In order to understand the great assistance of the spectroscope in scientific colour work, we must consider the nature of this discovery, which has already proved so valuable in other branches of science.

CHAPTER III

EXAMINATION OF THE SOLAR SPECTRUM—DARK LINES—LOCALITY OF THE COLOURS—THE SPECTROSCOPE: ITS CONSTRUCTION—ABSORPTION SPECTRA—COLOURISTS' USE OF THE SPECTROSCOPE.

§ 20. If sunlight be admitted through an exceedingly fine slit and examined with the prism, it will be noticed that the spectrum obtained is not perfectly continuous, but is crossed by many minute parallel lines or gaps. These "dark lines" were first described by Wollaston in 1802, and in 1814 Fraunhofer, a German optician, counted as many as 600, and mapped them out in their proper positions on the spectrum chart; hence they are often termed the "Fraunhofer lines." These fine dark lines are "*fixed*," never varying in their position. They are, therefore, of the greatest assistance to colourists when describing, with scientific accuracy, the exact locality of any colour in the spectrum. These lines are always found to occupy precisely the same places, and therefore serve as infallible landmarks, or lines of reference, for specifying accurately any portion of the solar spectrum. To the principal lines have been given the letters of the alphabet, beginning at the red end, thus A, B, C, to H in the extreme violet. By this means the various colours of the spectrum can be easily identified. As these dark lines are being continually referred to in colour science, the student should note carefully, and commit to memory, their position in the spectrum. Thus, at the extreme red end of the spectrum is a strong line A (see Fig. 7). B and C are in the cherry-red D is the strong and characteristic line found

in the orange-yellow. (With a powerful spectroscope the D line is seen to consist of two lines close together.) The two prominent lines in bright green are the E lines, F is in

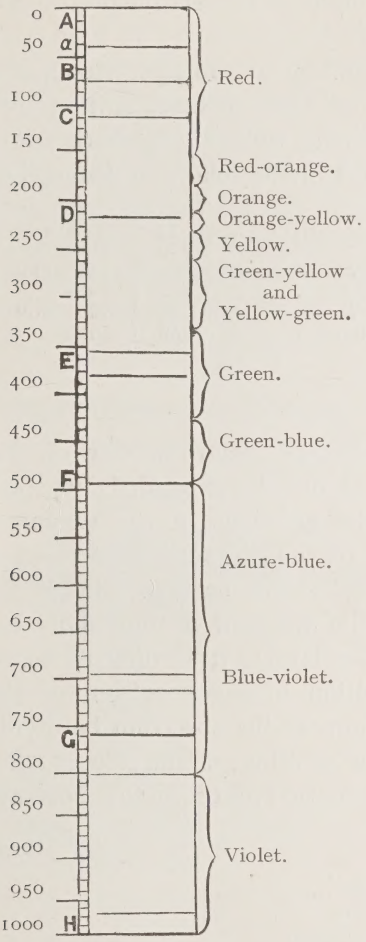


FIG. 7.—Prismatic solar spectrum, showing principal dark lines and the locality of the fundamental colours.

the green-blue, G is in violet-blue, while the two lines H

are in the extreme violet. Between these principal and outstanding lines are a great number of others, of less importance to the colourist. Fig. 7 represents the prismatic solar spectrum with the relative positions of its characteristic fixed lines.

§ 21. According to Professor Rood, of Columbia College, who has made elaborate investigations on this subject, 1,000 parts of ordinary white sunlight are composed of differently coloured rays in the following proportions:

Red	54	Yellow-green	121
Orange-red	140	Green and blue-green	134
Orange	80	Cyan blue	32
Orange-yellow	114	Blue	20
Yellow	54	Blue-violet	20
Greenish-yellow	206	Violet	5
			1000

In the prismatic spectrum, shown in Fig. 7, the blue and violet end is unduly expanded; whereas in a diffraction spectrum the positions of the various colours are more equalised. In the diffraction spectrum the sodium line D in the orange-yellow occupies almost a mid-way position. Owing to the want of a thoroughly accurate system of colour nomenclature, it is difficult to state correctly the precise position in the spectrum of the various typical colours. Suppose the spectrum be divided into 100 parts, the following positions of the colours will be approximately true for prismatic and diffraction spectra.

	Prismatic	*Diffraction*
Red	10	20
Orange	20	40
Yellow	25	45
Yellow-green	35	55
Green	45	65
Green-blue	55	75
Blue	65	85
Blue-violet	75	90
Violet	90	95

§ 22. The spectra given by other sources of light, such as the electric arc, oil lamp, or coal gas, are all continuous: that is, they do not show the presence of any dark lines, and differ therefore from the spectrum of sunlight. The existence of these lines is caused by the absorption of the light in passing through the glowing vapour of metals and other elements present in the sun's atmosphere; each substance in the state of a vapour having the remarkable power of absorbing, or of being opaque to, the same kind of rays as it emits. After long and laborious research, Fraunhofer, Kirchhoff, Bunsen, and others established the law that *every substance which emits at a given temperature rays of certain orders of refrangibility possesses the power, at that same temperature, of absorbing rays of the same order of refrangibility.*

§ 23. **THE SPECTROSCOPE: Its Construction.**—Before proceeding to study the science which underlies the art of

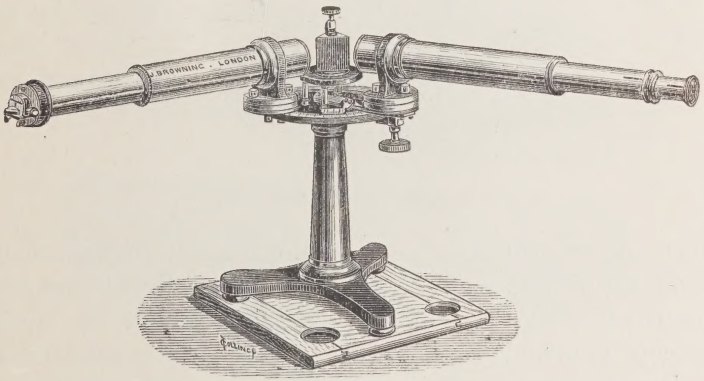


FIG. 8.—One-prism spectroscope.

colour-mixing, it may be well to devote a little attention to the construction of the spectroscope: an instrument which has now become invaluable in the hands of the scientific

colourist for determining the true interpretation of colour-mixing phenomena. As the naked eye is unable to *analyse* light, or to distinguish the differently coloured rays emitted by a coloured object, it is necessary to enlist the aid of the prism in all experiments where the component rays of a colour have to be separated. A convenient form of apparatus for this purpose is found in the spectroscope, a word which means literally an instrument for *viewing an image* (Lat. *spectrum*, an image, and Gr. *skopeo*, I view). It consists of

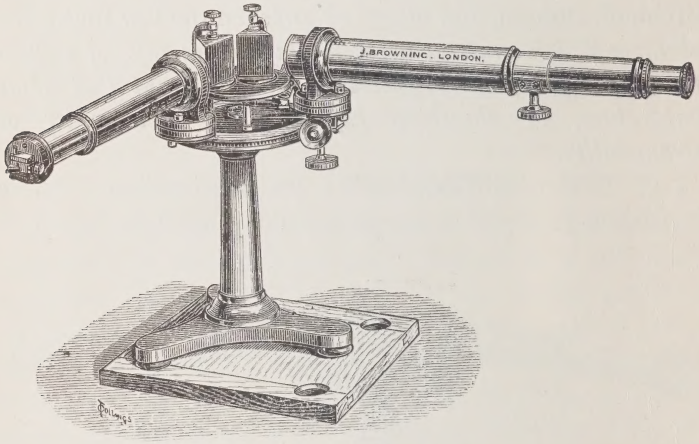


FIG. 9.—Two-prism spectroscope.

one or more prisms so arranged that the spectrum, instead of being thrown upon a screen, can be examined directly through a telescope. To the scientific colourist the spectroscope is invaluable, as by its aid the various differently coloured rays constituting a colour are separated or analysed, and the true nature of any coloured light—whether homogeneous or mixed—can be accurately determined. In our illustration (Fig. 8) we have a simple form of spectroscope by Browning with one prism, and Fig. 9 with two prisms.

The instrument is firmly fixed upon an iron stand. The coloured light to be examined enters by the tube having an extremely fine slit made by two knife edges (see left of illustration), the width of the slit being easily regulated by means of a screw. After passing through this very fine slit the light is made to pass through a convex or collimator lens, whereby the rays of light are made parallel before entering the prism. By this arrangement a purer spectrum is obtained. The light, having been refracted and decomposed in passing through the prism or prisms, is made to enter the second tube, which consists of a telescope ; and the image of the spectrum is magnified before it reaches the eye. The telescope tube is so made as to be movable round a graduated circle which enables the observer to adjust the instrument to any desired part of the spectrum. A finely graduated scale or vernier (which can be seen in Fig. 8) is employed for purposes of measurement, or for locating with accuracy the position of the dark lines in that part of the spectrum under special examination. Most spectroscopes have also fixed to the slit a simple reflecting prism for allowing two spectra to be examined side by side simultaneously.

This little device is useful where two different absorption

FIG. 10.—Direct-vision spectroscope.

spectra are to be carefully compared with each other, or where the spectrum of white light is wanted for comparison. For colour chemists a most useful form of spectroscope is that known as the compound direct-vision instrument (seen

in Fig. 10), having several prisms composed of crown glass and flint glass arranged alternately. This form of spectroscope gives wonderful results, considering its small size.[1]

The compound prism is placed inside the brass tube, at one end of which is the slit for admitting the light. This can be widened or narrowed at pleasure by turning round the ring with the milled edge, seen at the slit end of the spectroscope (see right of illustration). This little instrument, though readily carried in the waistcoat-pocket, gives excellent results. It shows the principal dark lines of the spectrum, as seen in Fig. 7, and reveals to the colour chemist the characteristic nature of the absorption bands of the dyed materials, colours, or dye solutions under examination.

§ 24. **Use of the Spectroscope in Colour Examinations.**—Though the spectroscope has now become of much value in many branches of scientific research, its employment in the domain of colour chemistry is, to a certain extent, more limited. Some dyestuffs and colouring matters of totally different chemical constitutions may yet show similar *absorption spectra* on being examined with the spectroscope. Before proceeding, it may be well to explain more fully this term "*absorption spectrum*," which will be used frequently during our study of colour-mixing phenomena.

§ 25. We have already learned that all solid bodies, when heated to a white heat, give a *continuous* spectrum ; that is, one which is not broken by any minute dark lines or bands like that in the sun's spectrum. The light from the electric arc, an oil lamp, ordinary coal gas, acetylene gas, or from a candle are all examples of illuminants giving a continuous spectrum. If a glass beaker containing a dilute solution of a yellow dye such as any of the aniline yellows be placed

[1] For more advanced work the student is referred to the many excellent works on spectroscopy, describing the methods of accurately measuring the localities of colour absorption and of photographing the absorption spectra of the various dye solutions.

between any of these lights and the slit of the spectroscope, it will be found that the light transmitted through the yellow dye has undergone a change. While all the rays of the spectrum, stretching from the red to the green, are freely transmitted, the blue and violet end of the spectrum is absent—a total extinction or absorption of these coloured rays having taken place. The result is an incomplete or *absorption* spectrum, certain of the coloured rays having become *absorbed* in the passage of the light through the yellow solution. The *locality* of absorption is determined by means of the fixed dark lines of the spectrum, which, in this case, starts between the lines F and G in the blue, and continues

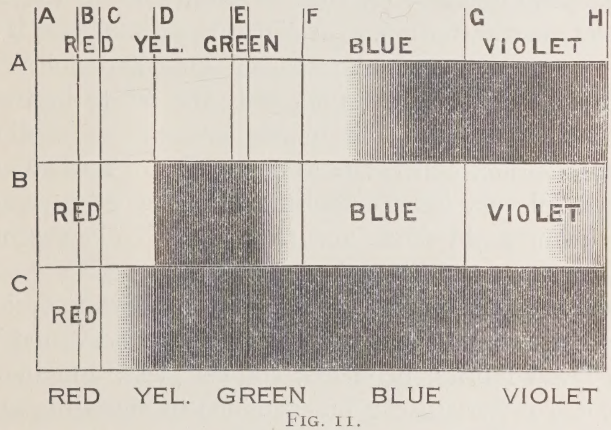


FIG. 11.

A = Representing the absorption spectrum of metanil yellow.
B = Magenta (dilute) showing transmission of red, blue, and violet.
C = Magenta (strong) showing transmission of red rays only.

all the length of the spectrum to the H line in extreme violet. A simple way of representing the absorption spectrum of a yellow dye would therefore be as represented in Fig. 11 (A) : the shaded portion of the spectrum showing where the colours are absorbed or absent. Such an experiment also shows that a yellow dye does not appear yellow simply

because it transmits the yellow rays of the spectrum, but because it absorbs that part of the spectrum complementary to yellow, i.e. blue and violet. The unabsorbed red, green, and blue-green rays are combined on the retina of the eye, and produce the sensation of seeing yellow. Thus yellow is not a pure or monochromatic colour, but consists of red and green rays.[1]

Another simple example of an absorption spectrum will be found by viewing with the spectroscope a dilute solution of the beautiful pink dye, magenta. In this case the greenish-yellow and green rays are absorbed, making a dark break or *absorption band* from the line D in yellow to nearly line F in the blue-green (see Fig. 11, B). In dilute solution the blue and violet are transmitted, with slight absorption ; but, if the solution be strengthened, all the green, blue, and violet rays are completely absorbed, leaving only the red to be transmitted. This explains the bluish-pink hue of a dilute magenta solution, and the pure cherry-red of a more concentrated solution (see Dichroism, § 39). The absorption spectra of magenta *dilute* and *strong* may be represented as in Fig. 11, B and C.

For other examples of colouring matters showing decided and characteristic absorption bands see Chapters IV. and VI.

§ 26. Dyed fabrics, pigments, stained glass, and indeed all coloured materials, can be examined in much the same manner with the spectroscope. In all cases an absorption spectrum is obtained ; but that given by solutions, where the light is transmitted through the liquid, is purer than what can be obtained by viewing the reflected light from dyed or coloured surfaces. Reflected coloured light contains a certain admixture of white light (reflected unchanged from

[1] Although yellow is considered a primary colour, when dealing with paints and dyes, it is nevertheless a secondary or compound colour because it is formed by the combination of red and green light.

the surface of the material), which tends to impair the sharpness of outline in absorption spectrum.

The prism of the spectroscope analyses the coloured light into its constituent rays, and in colour chemistry there are many instances where spectroscopic examination is of the greatest importance. This is particularly so when certain colouring matters show decided and easily recognisable absorption bands on the addition of different chemical reagents. Thus the spectrum of the well-known colouring matter alizarin, or madder, is unmistakable when examined first in aqueous solution, then with the addition of a few drops of ammonia. Its alcoholic ammoniacal solution also gives a characteristic absorption spectrum. The spectra of chlorophyll (the green colouring matter of leaves and plants), of blood, of acid extract of indigo, methyl violet, eosine, magenta, of litmus in acid and alkaline solution, and many others are of much interest. Solutions of the aniline dyes will be found interesting and instructive subjects for spectroscopic study, as they possess sharp and decisive absorption bands.

§ 27. In studying the various phenomena of colour-mixing the analysing power of the prism not only reveals the true nature of the coloured light, but also the cause of many unexpected modifications in hue which many colours undergo when viewed in artificial light.

Two pieces of dyed material may match each other closely in colour when examined in good daylight, and yet present a considerable difference in appearance when viewed in a yellow illuminant like ordinary coal gas, or candlelight. Every practical dyer and colourist could give many instances from his own experience. This difference in behaviour between two colours apparently identical is due to the fact that colours, similar to the naked eye, may have a different optical composition, or be produced by the combination of

different parts of the spectrum. The naked eye is unable to separate the various coloured rays constituting a mixed colour, and cannot, therefore, tell a pure or homogeneous colour from a compound one. Two shades may appear identical to the unaided vision, and yet be composed differently and have different absorption bands in their spectra. For example, the eye cannot distinguish the difference between ordinary white light composed of all the colours of the spectrum and the white light produced by combining green and purple or red and blue-green lights together. The prism, or spectroscope, would at once reveal the difference. Dyed materials often show unexpected appearances when viewed in gaslight, and in such cases the spectroscope is of much service to the colour chemist and dyer in enabling him to discover the cause of such modifications. In colour mixing and dyeing it will be found that a knowledge of the optical properties of the dyestuffs employed is of some little service in producing the desired shades. It is, indeed, one of the first duties of the colourist to examine what is termed the " mixing qualities " of the various colouring matters placed before him and to determine their capabilities of producing good, useful shades by admixture with others. By viewing with the pocket spectroscope samples dyed with any colouring matter, he can tell whether the colour can be employed for producing certain desired effects. Blues, for example, which show a ready transmission of the red rays, cannot be employed in making a pure and brilliant green by admixture with yellow. Reds which transmit a certain amount of the blue rays are found to become bluish when diluted or reduced to produce tints and cannot be used for making pure scarlets. By carefully examining the absorption spectrum of a dyestuff, any little optical peculiarities can be readily detected which would otherwise pass unnoticed until the colours were

mixed or dyed. This explains why colours, when mixed with others, often do not give the results expected by the dyer. A little previous spectroscopic examination might save the colour-mixer some trouble.

The small direct-vision instrument, already referred to at Fig. 10, is most convenient for such work. Dye solutions give much more decided and characteristic absorption spectra than the same dyestuffs when dyed or printed on any material, either wool, silk, or cotton, as a quantity of white light is always reflected from the surface of the fabric. This tends to dilute, and render less decisive, the absorption spectra of the dyes. The positions of the absorption bands of the dye solution and of the dyed material are generally identical ; except when the property of dichroism (see § 39) is present to any great extent in the dye solution.

CHAPTER IV

COLOUR BY ABSORPTION

ABSORPTION OF COLOUR PRODUCED BY ADMIXTURE—ABSORPTION SPECTRA—SOLUTIONS AND DYED FABRICS—LUMINOSITY CURVES—ABSORPTION CURVES—DICHROISM—DICHROIC COLOURED FABRICS IN GASLIGHT.

§ 28. THOUGH the exquisite hues produced by the interference and dispersion of light are of great interest to the philosopher, they do not play so important a part in our everyday life as the colours produced by *absorption*. It is owing to this phenomenon that all the common objects of nature owe their colour. The green of the grass, the changing hues of spring, summer, and autumn foliage, the blueness of the sea, the glorious variety of colour displayed in flowers, the colours of the artist, the glass stainer, the calico printer and dyer, are all due to selective absorption.

When two coloured solutions are mixed together, or two differently coloured glasses viewed through each other, the resulting colour obtained is that which is transmitted by both colours in common. Thus, when yellow and blue dyes are mixed, or when a yellow slip of glass is viewed through a blue one, a green is produced. The true interpretation of this simple experiment is readily found by examining these two colours with the spectroscope. The green colour is produced, not because yellow transmits only yellow rays and the blue only blue rays, but because green is the only colour common to them both, all the others being more or less absorbed or quenched. All yellow pigments and dyes are found to

consist not only of yellow, but red, orange, and green rays (see A, Fig. 11). As already observed in § 25, all ordinary colours (except the pure spectrum colours) are compounds, i.e. they reflect to the eye many differently coloured rays, which, however, cannot be distinguished or separated by the naked eye. Blues are likewise found to reflect, not blue rays only, but varying proportions of green, violet, and a little red light. When two such colours as the yellow and blue are combined together it will be found that *green* is

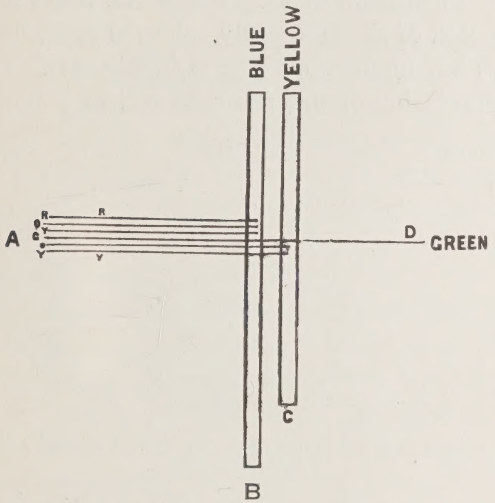


FIG. 12.—Showing production of green by combining blue and yellow glasses.

the only colour common to both of them, and is therefore freely transmitted, the others being more or less absorbed. This, then, explains why a green is produced by the combination of yellow and blue.

§ 29. This may be more readily explained by the aid of the above diagram (Fig. 12), which represents a ray of ordinary white light (A), composed of its red, orange, yellow, green, blue, and violet colours, passing through a sheet of

blue glass (B) and a sheet of yellow glass (C). The light (A), in passing through the blue glass, loses three of its constituent rays, those of red, orange, and yellow, which are absorbed or quenched, and are therefore not transmitted, while the green, blue, and violet rays are allowed to pass through freely. These, on entering the yellow glass, are not all transmitted. As yellow does not transmit or reflect any blue or violet light (see spectrum A, Fig. 11), these coloured rays are quenched or absorbed, leaving only the green to pass through alone. Hence the white light, which was composed of six differently coloured rays, has only the green rays left unabsorbed (see D in Fig. 12). Such is the true interpretation of this common fact of yellow and blue

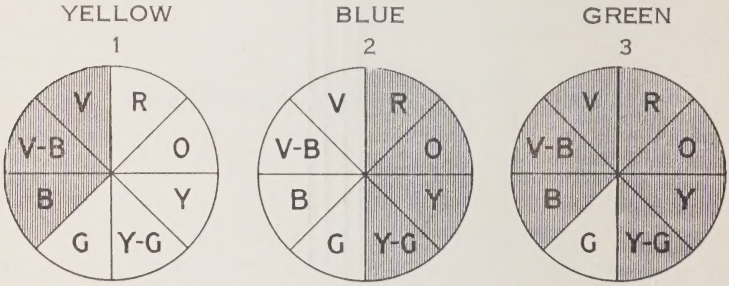


FIG. 13.—Chromatic circle, showing production of green by the admixture of yellow and blue.

producing green. If an optically pure blue and yellow could be obtained the result on admixture would not be a green, but probably a whitish grey; as the combination of blue and yellow *lights* produces a white (see Fig. 3, Plate III).

The effects of colour absorption by admixture or combination may be illustrated in a very simple manner by employing a chromatic circle. The circle in our illustration (Fig. 13) is divided into eight parts, representing roughly the various coloured rays constituting white light, i.e. red,

orange, yellow, yellow-green, green, blue, violet-blue, and violet. These are designated by their initial letters. By using shading lines to represent where absorption of colour takes place, we may show that the colour produced by admixture is the sum of the unabsorbed colour rays ; or, in other words, those rays which are common to both colour constituents. Thus, in No 1, Fig. 13, yellow reflects from red to green, and absorbs blue, violet-blue, and violet. Blue No. 2 reflects from green to violet, and absorbs all the other colours. If these two discs be placed one upon another as at 3, it will be observed that green is the only colour common to both, and is therefore freely transmitted.

This characteristic example of colour absorption may be illustrated in another way by means of the absorption spectra of the component colours. It is well known that any aniline yellow combined with a blue such as indigo extract produces a fairly good green when dyed together. This, as we have already learned, is not because the indigo reflects, or allows to be transmitted, only the blue rays, and the yellow only the yellow rays, but because, when both of them are combined, the green is the only colour which is freely transmitted by both of them. Fig. 14 is a representation of the two absorption spectra (A and B). A represents an aniline yellow and B the indigo extract, while C shows the combination of the two. The lines A, B, C, etc., represent the fixed or Fraunhofer lines of the solar spectrum —the invaluable landmarks to the colourist (see § 20).

A represents the absorption spectrum of a yellow, showing that this dye absorbs the violet, blue, and blue-green end of the spectrum, which is shown in shade (denoting absorption or absence of colour), while the remaining colours of the spectrum—green, yellow, and red—are freely transmitted.

B may be taken to represent the absorption spectrum of acid indigo extract, which shows strong absorption from the

red, near the line B, through the orange, yellow, and yellow-green to the green at the lines E ; while the extreme red, the green, blue, and violet are freely transmitted.

When these two spectra are combined, as represented in C, we find that only the extreme red, the green, and the blue-green are transmitted, which constitute the green colour obtained by combining aniline yellow and acid indigo extract. Such a green as the above cannot be of a perfectly pure bright hue from the quantity of red light it reflects ; but if, instead of indigo blue, a purer aniline blue or a greenish blue

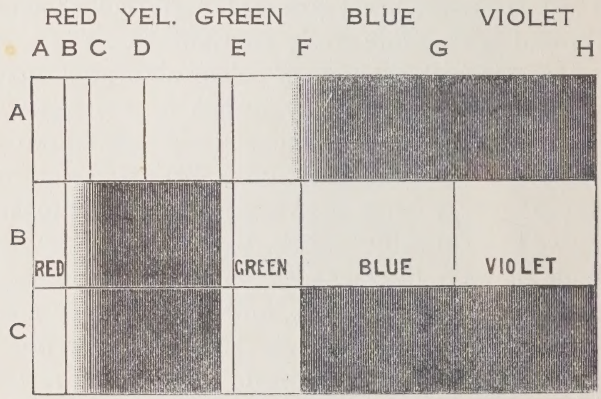


FIG. 14.—Green produced by admixture of yellow and blue.
A shows the absorption spectrum of a yellow.
B the absorption spectrum of indigo extract.
C shows the coloured rays transmitted by A and B resulting in a green.

be taken, reflecting little or no red light, then a purer and brighter green will be the result.

§ 30. When there is absorption of coloured rays by the admixture of two colours, there is produced a corresponding loss of light, or a darkness in the colour. This explains the dull appearance, or what is termed the " sadness " of all mixed shades. The more different colours there are present in a mixture, the darker, or more approaching to grey, is the

result. It has been well said that "every admixture of colour is a step towards darkness." Two colours, which cut off between them all the coloured rays of light, when they are combined, either on the palette or in the dye-bath, produce an extinction of light, or, in other words, a black (see Fig. 15).

§ 31. In dyeing, it is seldom that two complementary dyestuffs can be found to fulfil the exact requirements in this respect, as all of them, more or less, transmit some rays in common; but by employing three dyestuffs a good pure black can be obtained. A mixture of red and a blue-green, such as carmoisine WS and acid-green G, if sufficiently strong will dye a black. This may be seen on dyed Pattern Plate No. I. at the end of the book. No. 1 is carmoisine WS, 2 is acid-green G, while 3 is a good black, dyed by combining them together. All the rays transmitted by the one are

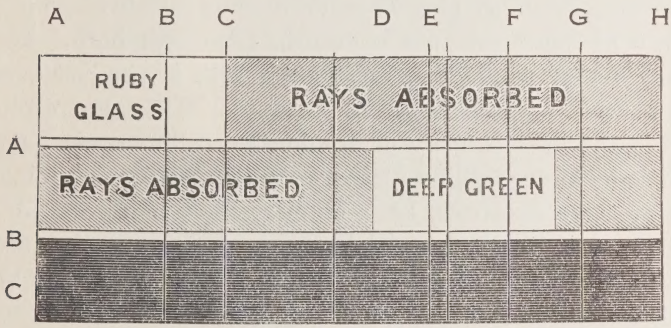


FIG. 15.—Total absorption or blackness produced by combination of red and green glasses.

absorbed or quenched by the other. Another good example of this total extinction of light by two coloured bodies may be found by viewing through a piece of ruby glass and signal green glass superimposed. If these two coloured glasses be placed together and held up to the light, it will be found impossible to see through them. All light is quenched and

total darkness is the result. This may be readily explained by the help of Fig. 15. Spectrum A represents that of the ruby glass, showing the transmission of only the red and orange-red rays from A to C ; the other rays of the spectrum being absorbed, are shown by shading in the diagram. This may also be taken to represent the absorption spectrum of carmoisine WS (see No. I. dyed Pattern Plate at end). B represents the absorption spectrum of the green glass, known as " signal " green, which, as seen from its spectrum, transmits only the yellow-green, green (lines E), blue-green and blue (line F), while the remaining parts of the spectrum, from red to yellow-green, and from blue to violet, are all completely quenched. This absorption spectrum of " signal green " glass may be taken also to represent that of acid green G, which it closely resembles in colour (see No. 2, Pattern Plate). Thus it is readily seen that if two such colours are combined they have no coloured rays in common ; no ray of light can pass unabsorbed through both. The result is that total darkness, or a black, is produced, as represented at C, see also dyed pattern 3. The same results can be got in dyeing by combining Roccelline or fast red with some of the aniline greens. By the suitable combination of three dyestuffs, i.e. metanil yellow, indigo carmine and carmoisine WS, beautiful shades of grey are obtained (see the dyed specimens, Nos. 7, 8, 9, at end of the book). Their formation can be explained in the same manner.

The fact of a certain amount of grey or black being produced by the admixture of certain colours is largely taken advantage of by dyers and colour-mixers in producing soft or what are often termed " broken " or " sad " shades. These are described in Chapter VIII.

Complementary dyes and pigments produce greyness or black when mixed ; whereas complementary *lights* (as described in Chapter V.) produce whiteness.

§ 32. The behaviour of dyestuffs in dyeing the various textile fibres is similar to that of superimposing coloured glasses or the mixing of liquids we have just studied. The fibres are dyed through to the inside, and, being in themselves translucent, the light enters to a certain depth within the fibre, when it is again reflected. During its passage through the dyed fibre or fabric, certain coloured rays have been absorbed, while the remaining rays are reflected to the eye. In this way the colours dyed on fibres are similar to those obtained from the solutions of the dyestuffs. There is, however, one great difference between a dyed fabric and a dye solution. The light transmitted through a coloured solution is richer, and more saturated, than the same colour dyed on a fabric, owing to the fact that a certain amount of unchanged white light is reflected from the surface of the fabric, thus giving to the dyed colour a paler and less saturated appearance. The reflective power, or the *lustre* of a fibre, is, therefore, a most important feature in the question of dyeing. If we examine the fibres of silk and wool together, we find that silk has a much greater lustre than wool, i.e. it reflects to the eye, in certain directions, a larger quantity of white light from its surface. Thus the coloured light reflected from dyed silk may be much lighter, or it may be much deeper and richer in hue than that of wool dyed with the same dyestuff. Lustrous fibres, like silk, china grass, the various artificial silks, and some of the high lustred wools, can show, according to their optical position, rich full colours, almost free from any admixture of white light ; or they may reflect, in unfavourable positions, a great deal of white surface light, producing a paler tint of colour. It is this sheen, or surface reflection of highly lustrous fibres, that gives to many dyed woven fabrics their beauty and sparkle, making the lustreless fibres like cotton, or the lower class of wools,

comparatively poor and dull in comparison. If cotton be compared with wool in the same way, it will be observed that wool surpasses cotton in lustre, the latter appearing a dead, sheenless white. It follows, therefore, that the colours dyed on wool appear richer than on cotton. This is found to be so in practice, as it is most difficult to match accurately shades dyed on cotton with those dyed on wool, silk, or the finer qualities of jute. A lustreless fibre like cotton scatters its surface light in all directions, giving to the colours dyed on it a somewhat opaque, dull appearance, when compared with those dyed on wool.[1] The lustre of the fibre is a most important question to the dyer and textile colour matcher. This has been treated more fully in a companion volume on *Colour Matching on Textiles*.[2]

§ 33. Another instructive example of colour absorption may be seen in the blue colour obtained by mixing together green and violet (see Fig. 16). A fairly good blue may be dyed on wool or silk by using an aniline green, such as malachite, or china green, along with a suitable proportion of methyl violet 2 B. A light sky-blue dyed in this manner may be seen at Pattern Plate II., No. 4, at end of book. Such a blue is indeed sometimes sold under the name of "indigo substitute." The formation of this blue colour may be understood after a spectroscopic examination of these two colouring matters. Greens, such as malachite green A, transmit or reflect not only the green rays but a considerable portion of the blue and a little of the violet; while violets like methyl violet 2 B, reflect, along with the violet rays of the spectrum, a large quantity of blue and also red rays. When two such colours as these are combined, it will be found that the blue rays are the only ones freely

[1] With "mercerised" cotton, where the sheen and lustre of the fibre equal that of silk, the dyed colours appear as rich and saturated as those on silk itself.

[2] Published by Scott Greenwood & Son, London.

transmitted, being common to both colours. The green absorbs the red and most of the violet, while the violet absorbs the orange, yellow, and yellow-green, leaving blue rays to predominate. This gives to the mixture its blue colour. A clearer idea may be obtained by studying the representations of their absorption spectra at Fig. 16.

A represents the absorption spectrum of an aniline dye such as malachite green A. The absorption continues

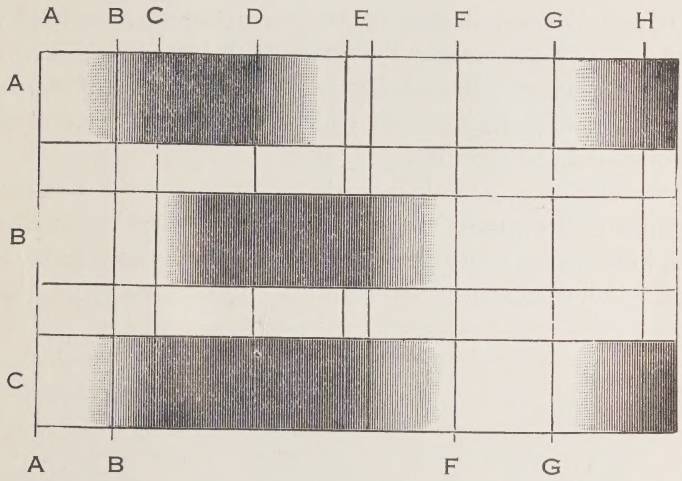


FIG. 16.—Showing production of a blue by admixture of green and violet.
A. Absorption spectrum of malachite green crystals A.
B. ,, ,, methyl violet 2 B.
C. ,, ,, blue obtained by their combination.
For dyed pattern see Plate II. at end of book.

strong from line B in the red to D in the yellow. The extreme red is transmitted along with the green, blue-green and blue rays extending from E to G, while the violet at H line is absorbed.

B represents the absorption spectrum of methyl violet 2 B showing the free transmission of the red part of the spectrum, and likewise the bluish green, blue, and violet; while the

orange, yellow, yellow-green and green, extending from C to nearly E½ F, are absorbed.

C represents the light transmitted through both spectra and shows the absorption spectrum of the composite blue. All the coloured rays are quenched, excepting the blue and green-blue at lines F and G, and extreme red, A and B, which combine together in the eye to produce the sensation of a blue (see also § 61). The same result may be simply represented with the chromatic circle, as in Fig. 17.

Though the few examples we have studied are simple, they are sufficient to show the fundamental law that governs all the varied phenomena in the production of colour by absorption, and the science which underlies the simplest experiment in colour-mixing.

§ 34. For the careful investigation of all such colour phenomena the spectroscope is invaluable. But it is necessary, in writing about colour and colour absorption, to have some graphic means of representing the various intensities

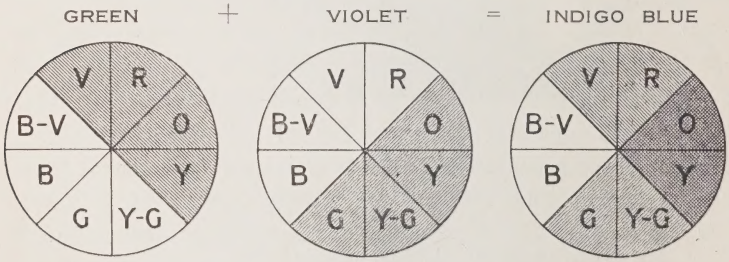


Fig. 17.—Showing formation of a blue by admixture of green and violet.

of absorption or of reflection in a colour spectrum. It is difficult to represent this by means of shading in varying degrees of depth, according to the degree of absorption, as in Fig. 16 ; but there is another simple method whereby this difficulty is removed, and we are enabled to express clearly and accurately the various characteristics of any colour.

This graphic representation of an absorption spectrum is accomplished by means of a curve, which is drawn on a diagram representing the solar spectrum, with its principal fixed lines to serve as reference marks. These curves represent, by their varying heights on the chart, either the different degrees of :

(1) Luminosity (brightness of the reflected colour) ; or,

(2) Absorption (darkness of the colour in the spectrum). Some writers on colour employ the *luminosity* curve ; while others prefer to represent the spectrum of a colour by its *absorption* curve. Either of the two methods can be employed, but the writer has adopted, with the exception of Figs. 18 and 19, the *absorption* curve in his diagrams illustrating the various spectra of dyes and coloured fabrics. Though these curves are, for the first time, somewhat perplexing to the colour mixer and dyer, they are well deserving of study, as they are of much assistance in interpreting many colour phenomena which would otherwise remain to him a mystery ; and they also reveal, at a glance, the optical nature of a colour or dye, which would require pages to describe as fully.

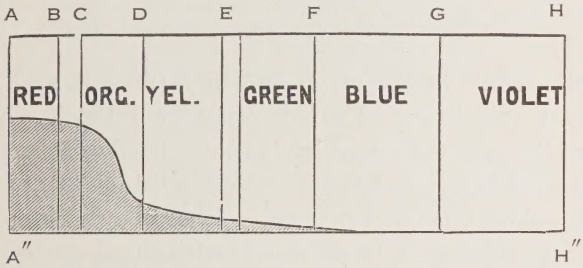


FIG. 18.—Spectrum showing locality and intensity of coloured light transmitted by ruby glass. The shaded curve represents the *transmitted* light.

§ 35. (1) **LUMINOSITY CURVES.**—By the first method the brightness of the reflected or transmitted colour is represented by the height of the curve. For example, let the

rectangle AH, A″H″, Fig. 18, represent the solar spectrum, with all its different colours arranged in the usual order of red, orange, yellow, green, blue, and violet, in their natural brightness. The letters A, B, C, D, etc., represent the prominent fixed lines present in the sun's spectrum, which are the invaluable landmarks in determining the positions of the different colours. We have already learned that ruby glass transmits the red rays : from A to B, with a little of orange between C and D. This, then, can be represented in diagram form by drawing a curve at that part of the spectrum (see Fig. 18) which will be highest in the red at A and B, showing the part of greatest brightness, while it rapidly falls in the orange between C and D. At the yellow part of the spectrum D it has fallen almost to the base line, showing the small quantity of yellow which ruby glass

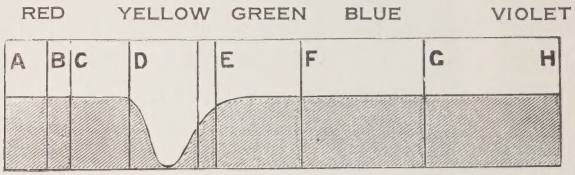


FIG. 19.—Spectrum showing the light transmitted by dilute solution magenta. Here the shaded portion represents transmitted light.

transmits, while in the green and blue (lines E and F) no light is transmitted. The quantity or intensity of the coloured light, therefore, which is transmitted or reflected by any coloured body can be represented in this simple manner.

If the colour known as magenta, either in a dilute solution or dyed upon a fabric, be examined with the spectroscope in the same way as the ruby glass, a reflected light curve is obtained which may be represented in Fig. 19, the shaded portion showing the reflected light. It will be seen from this curve that magenta, in its *light tints*, reflects the red, orange, and yellow rays to line D, but absorbs all the yellow-green

and bright green of the spectrum as far as the lines E, where it reflects all the rest of the rays from the blue to the violet.

§ 36. (2) **ABSORPTION CURVES.**—The second method is exactly the reverse of the first described, as with it not the brightness or luminosity is represented, but the *darkness* or absorption of the coloured rays.

For the purpose of illustration let magenta be again taken. Its absorption spectrum in Fig. 20 is represented according to two methods, i.e. A, by shading the absorbed portions of the spectrum, and B, by the absorption curve. It will be seen that the region of absorption lies in the brightest part of the spectrum, namely, from the yellow to the green (from lines D to E). The dotted line represents the absorption curve of a strong solution, or of a deep shade of magenta,

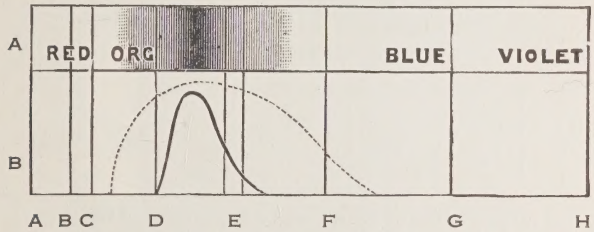


FIG. 20.—Absorption spectrum of magenta represented by shading (A), and by an absorption curve (B). The dotted curve represents a strong solution of magenta showing an increased absorption.

showing the much-extended absorption band. The richer the colour is, or the more concentrated the dye solution becomes, the absorption is the greater, and the light tends, more and more, to become monochromatic. A concentrated solution of magenta transmits only the red rays. The effect produced on deepening a dye solution, or in dyeing colours in varying strengths, is an important question to colourists, and will be considered specially under the subject of Dichroism (see § 39).

Fig. 21 represents, in the same way, the absorption

spectrum of a green dyed with naphthol yellow and indigo extract. A shows the method of representing the degrees of absorption by shading the spectrum, and B gives the corresponding absorption curve. It will be observed that the green consists of a *little red* at the lines B to C, *green, blue-green, and blue* ; while the remaining red, orange, yellow, most of the blue, and all the violet are absorbed.

In all observations of colours with the spectroscope it is best to employ either the purest sunlight, or, what is considered even better, the electric arc light. In order to give greater accuracy to the descriptions of colour spectra and absorption curves, with only the fixed lines as the reference marks, it is desirable :

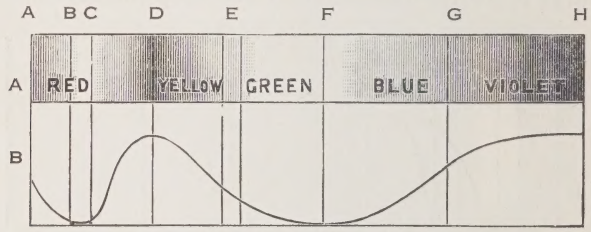


FIG. 21.—Representation of the absorption spectrum of the green produced by the admixture of aniline yellow and indigo carmine. A, intensity of absorption of spectrum shown by shading ; B, by the curve.

1st, that the *strength* of the colour solution be noted ;
2nd, that the *depth* of the colour solution be noted ;
3rd, that the absorption bands be carefully measured and reduced *to their wave-lengths.*

Small absorption curve diagrams, such as we have shown in Fig. 22 and elsewhere, give at a glance an amount of information regarding the optical structure of the colours, which would otherwise require lengthy description.

The following characteristic absorption spectra of six well-known dyestuffs may be taken as examples of colour absorption curves :

1. *Eosine* absorbs chiefly the green and blue-green rays E to F, while in a strong solution, or deep shade dyed upon wool (see dotted line), the absorption band is extended from nearly D in the yellow to beyond the line F in the blue.

2. *Orange G.*—There are many azo oranges, all of them giving a more or less similar spectrum. The orange here represented shows all the blue and violet end of the spectrum

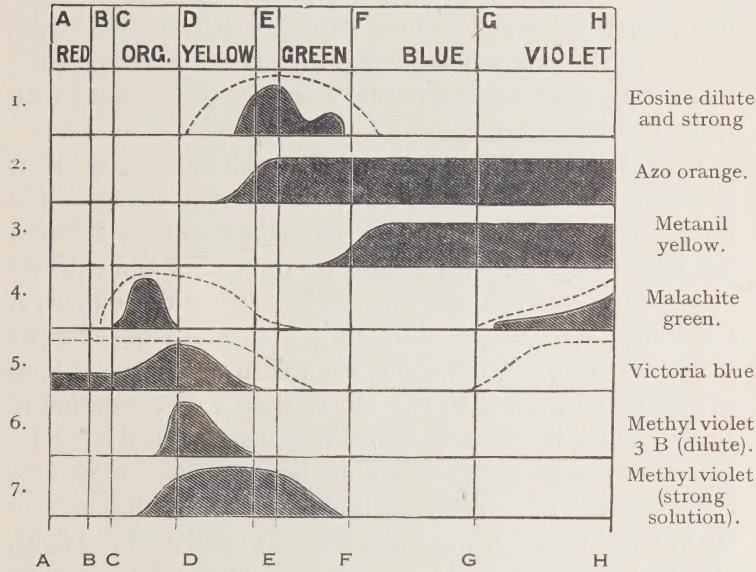


FIG. 22.—Examples of absorption spectra of dyestuffs. The dotted lines at 1, 4 and 5 represent strong solutions of the colouring matters, showing increased absorption.

absorbed as far as the E lines in green, where absorption gradually ceases towards D. The yellow, orange, and red are freely transmitted.

3. *Metanil Yellow* or other aniline yellows shows absorption of all the violet and blue-violet to the F line, where the absorption stops short in the blue-green, and gradually decreases towards the green If the yellow be of a greenish

cast, a slight absorption may be observed in the red. The spectrum of yellow is an instructive one, as it shows us that yellow dyes or paints are not yellow because they reflect only yellow rays, but because they absorb or quench all those rays complementary to the yellow, viz., the blue and violet. The red, orange, and green rays are reflected as freely as the yellow ones, but on entering the eye the red and green are combined to form yellow light with a proportion of white light, so that the yellow from naphthol yellow, picric acid, or any other yellow dye or pigment, is not a pure colour, but consists of compound yellow rays largely diluted with white (see also § 25).

4. *Malachite or China Greens.*—The rich blue-green colour given by this aniline dyestuff shows a strong absorption in the red-orange of the spectrum, extending midway between the lines C and D, with a faint absorption of the extreme violet. In a more concentrated solution (see dotted curve) the orange-red, orange, yellow and yellow-green and extreme violet are absorbed, extending from B to nearly the E lines in green, and from G to H. On viewing a deep solution of this dyestuff, it shows a redder hue than when dyed on a fabric, owing to the property of dichroism (see § 39, also coloured Plate II., Fig. 6). It is observed from this spectrum that malachite green transmits a large quantity of red light, along with the green, blue-green, and blue. Such a blue-green cannot produce so brilliant and clear a tone of green as one showing a greater absorption in the red.

5. *Victoria or Night Blue.*—This is a beautiful pure tone of azure-blue, and from its spectrum is seen to absorb a certain quantity of red, gradually increasing in absorption until yellow is reached (D), where the absorption is strongest. The curve line gradually falls as it approaches green, at the E lines, after which there is free transmission of all the other colours of the spectrum. This blue, from its tendency

to absorb red, and freely reflect all the green and blue, preserves its beautiful pure colour in gaslight, and hence often receives the name of " night " blue.

6 and 7. *Methyl Violet* shows strongest absorption in the bright part of the spectrum, in the yellow and yellow-green, while the red, orange-red, blue-green, blue, and violet are freely transmitted. 7 is a strong solution, and shows the greatly increased absorption—the band extending from the lines C to F. This shows that the magnificently rich violet colour of this aniline derivative—unequalled by any other colouring matter—is not due simply to its free transmission of the violet part of the spectrum, but to its absorption of those rays *complementary* to violet, namely, yellow and yellow-green. It is an interesting fact, which might be mentioned here, that the yellowish green metallic reflection of this dye, when in the solid, crystalline state, consists of that part of the spectrum which is absorbed when in solution, namely, yellow and yellow-green (see § 13).

§ 37. As nothing in nature is ever totally lost or destroyed, the inquiring colourist may ask himself the question: " What becomes of the coloured rays which are absorbed within a coloured substance? " They become changed from visible light into invisible heat. This explains the reason why black clothes are so warm to wear on a day of clear sunshine compared with light-coloured ones. All the light of the sun's rays is absorbed within the black material, and is there transformed into heat; while a light-coloured suit of grey, or white, absorbs little light and reflects much, and is, therefore, not warmed by the absorption of the light rays. This may be strikingly demonstrated by placing two pieces of velvet, one white and the other dyed black, upon a bed of snow during bright sunshine. After some time has elapsed it will be found that the black velvet, by its absorption of the rays of light, has become warmed and sunk down

to a considerable depth in the snow, by reason of the snow being melted by its heat ; while the white piece of material remains on the surface in the same position as when first placed. Having reflected all the sunlight from its surface, it has not become heated by absorption. All coloured materials absorb more or less of the sun's rays, and are accordingly warmer in bright sunshine than white material.

§ 38. All the examples we have given of the spectra of coloured materials and dyes show clearly the inability of the naked eye to distinguish between a pure and compound colour. Two colours dyed on cloth may appear identical to the eye and yet be composed in a totally different manner and show different absorption spectra. Hence arises the great value of the analysing powers of the spectroscope in revealing the true composition of any colour, by separating its several constituent coloured rays.

By carefully examining bright, or what are termed *luminous*, colours, like magenta, the eosines, or rhodamine pink—one of the most brilliant colours known to the dyer —it will be found that their brilliancy of hue is not due simply to the fact that they reflect or transmit that colour only, but because they absorb all the green and yellow-green part of the spectrum, leaving the red, orange, yellow, blue, and violet to be transmitted. These, when all combined upon the retina of the eye, produce the sensation of the beautiful magenta or eosine-pink colour. These coloured rays are present in such proportions as to produce, by their combination, a certain amount of *white light*, so that the brilliancy of magenta, rhodamine, and such-like colours is due largely to the re-formation of white light by the reunion of many of the coloured rays. We have already considered the case of aniline yellows (see § 36, example 3), which owe their luminosity to the combination of the complementary colours producing white. It is to the presence of this

recombined white light that a dye owes its brilliancy.

The sharper the absorption bands appear in a colour, the more luminous is that colour ; and when a dye shows more or less absorption all over the spectrum it can never be a bright and luminous colour.

§ 39. Before leaving the subject of colour absorption, it is necessary to pay attention to the interesting property of *dichroism*, possessed by nearly all ordinary colouring matters. If a ray of white light be passed through a strip of gelatine or glass coloured yellow, the transmitted light will, of course, be of a clear yellow colour. If, however, three or four similar strips be placed together and viewed through, it will be observed that the light is not a yellow similar to that obtained by viewing through the one thickness, but it has acquired a more orange appearance. If the number of coloured strips be doubled, the light transmitted will possibly be of a deep orange colour, and should the colour be transparent enough it might be possible to increase the number of yellow plates until a *red* colour was transmitted. The same phenomenon may be noticed in a solution of magenta. If the solution be very dilute, or the layer of coloured liquid be exceedingly thin, a beautiful bluish-pink colour is transmitted ; but if the solution be strengthened, or its depth be increased, the bluish hue vanishes and the magenta assumes a scarlet or even a ruby-red colour. From these simple experiments it may be seen that the colour of the transmitted light depends greatly on the strength of the colouring matter, or on the depth of the colour solution, through which the light has to travel. This change of hue or *dichroic* property is very marked in some substances—chromic chloride, for example, which is a green in thin solution, and a claret-red in a deep solution (see Fig. 23). A great many dyestuffs exhibit this property in a more or less marked degree, and those which show it too strongly

had better be discarded by the dyer and textile colour printer. They produce differences in hue between plain-surfaced and velvet-pile fabrics dyed with the same colouring matter ; and, likewise, in a series of gradating or " stepping " shades a different cast is produced in the lighter tints, which often proves disappointing to the colourist. For the effects of dichroism in dyeing see § 40.

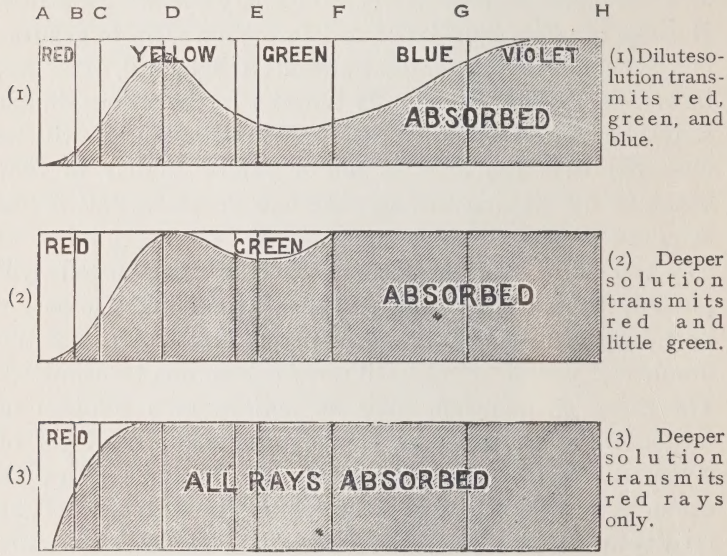


FIG. 23.—Absorption spectrum of chromic chloride, showing its change in colour from a green in thin solution (1) ; a dull red in a deeper solution (2) ; and a red in (3), where all rays are absorbed except the red.

Solutions of malachite green, archil, litmus, indigo extract, quinoline blue, methyl violet, and others show that the greater the depth of their solutions, or the more concentrated their colour, the redder in tone they become. They gradually lose, as their depth or strength increases, the green or blue rays observable in their more dilute solutions. One of the most interesting examples of a dichroic colouring matter is

quinoline blue, an aniline dyestuff which has now fallen into disuse. In dilute solution, or in a thin layer, it possesses a beautiful clear blue colour, while in a deep layer it assumes a fine red. This interesting property of dichroism may be readily studied by making a spectroscopic examination of the colouring matter with varying depths of solution.

A very dilute solution is examined first, and the absorption bands noted. The strength of the solution, or the thickness of the layer, is increased, and the corresponding increase of the absorption bands are again recorded.

It will be observed, as the strength of solution increases, that the dark bands in the spectum become broader and broader, until, in some cases, a large part of the spectrum is absorbed, and only one set of colour-rays is transmitted. For such experiments a wedge-shaped bottle or prism is generally used for holding the dye solution, as it can be made to show a gradual increase in the depth of the colour solution.

The following are a few of the colour changes due to dichroism :

Colouring matter.	*In thin layer.*	*In deep layer.*
Magenta	Bluish-pink.	Scarlet, or red.
Cochineal carmine	Bluish-pink.	Red.
Eosine and rhodamine pinks.	Rose-pinks.	Scarlets.
Picric acid	Greenish-yellow.	Pure yellow.
Gamboge	Yellow.	Orange.
Bichromate of potash	Yellow.	Deep orange.
Chromic chloride	Green.	Claret-red.
Sulphate of copper	Greenish-blue.	Pure blue.
Prussian blue	Sea-green blue.	Deep blue.
Quinoline blue	Clear blue.	Fine red.
China green	Bluish-green.	Blue-violet.
Above with few drops acid	Yellowish-green.	Claret-red.
Malachite green	Blue-green.	Reddish-purple.
Litmus	Blue.	Claret-red.
Acid extract of indigo	Greenish-blue.	Purply-blue.
Methyl violet	Blue-violet.	Red-violet.
Above with few drops acid	Violet-blue.	Claret-red.

In Fig. 24 is shown the gradual increase in the absorption

band of the beautiful pink dyestuff named rhodamine, a phthalein derivative. A dilute solution of a $\frac{1}{4}$-centimetre thickness presents a very delicate bluish-pink tint, and shows two absorption bands, one in the yellow-green, D$\frac{1}{2}$ E, and the other in the pure green at E. The absorption is strongest in the yellow-green (see (*a*)). The same dye solution, increased to $\frac{1}{2}$-centimetre thickness, appears to the eye a light magenta tint, which, on examination with the spectroscope, shows an increased absorption, the bands in the yellow-green and green becoming denser and broader (see (*b*), Fig. 24).

If the solution be increased to 1 centimetre thickness, one strong and decided absorption band is observed, the two bands having joined together, extending from immediately beyond the D line in the greenish yellow, through the E lines in the green, and gradually decreasing in absorption towards line F in the blue-green (see (*c*)). At 2 centimetres thickness, when the rhodamine solution assumes a rich magenta hue, a further increase in absorption is noticed, the band extending from D in the yellow to F in the blue-green, and also a slight decrease in the violet rays is observed.

At 3 centimetres a still further absorption takes place, and this increases gradually until at 5 centimetres the dark band extends from C$\frac{2}{3}$ D in the orange to azure-blue, F$\frac{1}{2}$ G, the blue being transmitted, absorption commencing again at the blue-violet, and continuing to the end of the spectrum.

At 10 centimetres thickness the solution, on viewing through that depth, is of a crimson-red hue, and, from its absorption band (see (*g*)), consists of red and orange-red from A to C and azure-blue between the lines F and G, all the other rays of the spectrum being absorbed.

At 20 centimetres depth, (*h*) spectrum, the solution appears to the eye of a deep scarlet or ruby-red colour, with no trace of a bluish or magenta hue. Its spectrum shows all

the blue rays are now absorbed, and total absorption extends from the violet end through all the colours to nearly C in the orange-red, so that the transmitted light consists of only red and orange-red rays.

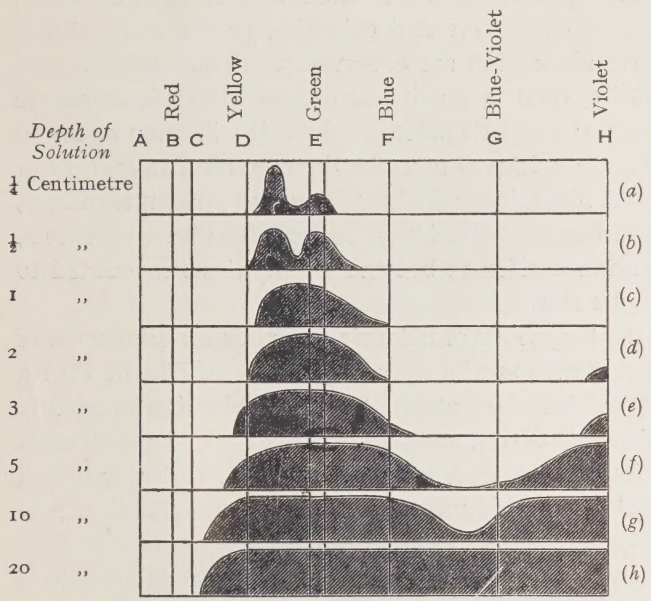


FIG. 24.—Showing gradual increase of absorption band of rhodamine pink on deepening its solution. The colour varies from a delicate bluish-pink (*a*) to a pure scarlet (*h*) at 20 centimetres thickness.

This example of rhodamine has been taken in detail, as it furnishes a good instance of what is termed *selective* absorption or dichroism, and shows how a colouring matter in dilute solution reflects or transmits a large number of coloured rays, which are gradually one by one absorbed as the colour is strengthened or its solution deepened.

In all such cases as we have given, the rates of colour absorption differ from each other ; certain coloured rays are absorbed and disappear, while the others are more freely

transmitted. Hence the transmitted light, being the sum of all the unabsorbed rays, must vary in its composition according to the concentration of the coloured solution, or the depth through which the light has traversed.

§ 40. The phenomenon of dichroism is one of much importance to the dyer and colourist, as the same effects of selective absorption are observed when colours are dyed upon fabrics, or in a much less degree when pigments are mixed upon the artist's palette. Thus it will often be found that reds, when diluted to make tints, go off into an orangy cast ; while blues, instead of reducing into pure tints of blue, become either greenish-blues or reddish-blues. Yellows, too, are often noticed to become " buffy " when reduced to form a light tint.

Thus the behaviour of colouring matters on dilution is of much importance to the dyer, because it is evident that a deep tone of blue or red may not give on reduction an equally balanced colour series, stepping gradually from the deepest tone to its lightest tint, without requiring to be tempered with another colouring matter to keep the series in a harmonious gradation (see Chapter V.).

A colour dyed on a velvet fabric having a plush pile is sometimes found to present a different hue from the same dyestuff when printed on calico or dyed on a plain-surfaced fabric. The repeated reflections within the minute interstices of the dyed velvet pile act in the same manner, and give the same effect, as the deepening of the colour solution, which results in the selective absorption of certain coloured rays. Thus, to take the example of quinoline blue as being the most characteristic, a plain surface of tapestry, or of calico, dyed with this colouring matter will appear much bluer in hue than when the same dyed material is seen with its cut edge as in a velvet pile. In velvet material the light penetrates deeply among the fibres, and becomes enriched

by repeated internal reflections. At each reflection a minute quantity of the blue and green rays is absorbed, which gradually increases the percentage of the red rays until as in its deep solution, the reflected light, after being robbed of its bluer rays, assumes a much redder hue.

§ 41. It will always be observed that colouring matters which show a tendency to transmit the red rays more readily than the blue and violet ones, appear much redder in artificial light, like gas, oil lamp, or candlelight. The quinoline blue, for example, is a fine blue by daylight and a reddish-violet by gaslight, owing to the facility with which it transmits red rays. This may also be noticed with dyed shades of methyl violet, which redden more in gaslight than a similar shade dyed with a non-dichroic violet.

Dichroism also explains the peculiar reddish tone seen on some of the aniline violets when dyed on silk.

Acid extract of indigo (indigotin disulphonic acid) is slightly dichroic, transmitting the red rays more freely, and this causes it to appear redder in gaslight than other blues which may match it perfectly in daylight. Several colouring matters, when combined to form compound shades, show a very decided dichroic property which makes them objectionable for dyeing. In such cases the lustre of the fibre and the texture of the dyed fabric effect a marked change in their appearance. Peculiar olive-green shades can be made by dyeing with naphthol yellow or fustic and methyl violet or acid violet (7 B), which show this property in a remarkable degree, appearing sages and olives on plain fabrics and calico, but changing to bronze and plum shades on a cut-surfaced or velvet pile. But we cannot enlarge further on this interesting branch of colour science. (For difficulties experienced in examining and matching such shades, the reader may consult the companion work on *Colour Matching on Textiles*.)

CHAPTER V

COLOUR PRIMARIES OF THE SCIENTIST *versus* THE DYER AND ARTIST—COLOUR-MIXING BY ROTATION AND BY DYEING—SECONDARY AND TERTIARY COLOURS—CONSTANTS—HUE, PURITY, BRIGHTNESS—TINTS, SHADES, SCALES, TONES, SAD AND SOMBRE COLOURS—COMPLEMENTARY COLOURS.

§ 42. EXCEPT in special cases of defective colour vision, the optic nerve is so constructed as to be capable of distinguishing three elementary colour sensations or primary colours, which produce, by their various degrees of combination, all the innumerable mixed shades to be found in nature. What these three primary colour sensations are has long been a moot point with philosophers; but, at the present day, nearly all authorities agree in selecting red, green, and violet as the three elementary sensations of colour.

This theory was propounded as early as 1802 by Dr. Thomas Young,[1] but it received little attention until it was re-established and developed by Helmholtz, Clerk Maxwell, Kœnig, and other scientists. This theory of colour is now generally adopted as the true one, as it explains satisfactorily all the various colour phenomena. It must not be forgotten, however, that in 1792 the German philosopher Wunsch selected these three so-called primary colours, which are now accepted as the best combination. But, wondrous to relate, this, the true primary theory, as expounded by Young and Helmholtz, seems to have been anticipated, centuries before,

[1] Born 1773 in Somerset. Professor Natural Philosophy in Royal Institution, 1801. Expounded doctrine of interference of light, which established the wave theory. Secretary Royal Society and eminent Egyptologist.

by the mighty "Master of those who know," Aristotle (300 B.C.). In his *Meteorologica*, iii. 2, he says:

"The colours of the rainbow are those which, almost alone, painters cannot make. For they compound some colours; but *scarlet, green,* and *violet are not produced by mixture,* and these are the colours of the rainbow."[1]

The old and most prevalent idea which has been known to painters and dyers from the earliest times is that **red, yellow,** and **blue** were the three elementary colour sensations.

This theory, however, is wrong as regards the mixture of absolutely pure colours such as found in the spectrum, i.e. coloured lights; but it is the only applicable standard for painters, dyers, and all those employing ordinary impure colours. If we might so express it, *the red, green, and violet are the theoretical primaries of the philosopher dealing with pure coloured lights; while the red, yellow, and blue are the practical primaries of all workers in ordinary colours like pigments, dyes, etc.* As the two theories are apt to prove confusing to the beginner, a few words of explanation may be useful.

The red, yellow, and blue theory owes its origin to a misinterpretation of the phenomena observed in mixing coloured pigments, dyes, or superposing coloured glasses, etc. The most distinguished defender of this doctrine in this country was Sir David Brewster, hence it is often known as the "Brewster theory." The laws regulating its phenomena have been elaborately wrought out by Chevreul, Hay, Redgrave, Field, and others, and, as it proves the only applicable standard to dyers and colourists, it remains their cherished theory. As we proceed, however, we shall understand more clearly the true interpretation of the various colour-mixing phenomena.

[1] For this extraordinarily prophetic statement the writer is indebted to Mr. W. Benson, in his beautiful work, *The Principles of the Science of Colour.*

In many cases the two theories have given rise to confusion of ideas. The student must ever bear in mind that the scientifically true primaries of the philosopher, who mixes pure spectrum colours and coloured *lights*, is one standard ; while the convenient primaries, red, yellow, and blue, of the artist and the dyer is an altogether different standard.

And why ? *Because the two theories are based on totally different colour phenomena.* In mixing coloured lights it is a matter of *addition* : in mixing dyes and pigments it is one of *subtraction.* The former may be represented by a plus (+) sign, the latter by a minus (–). When coloured lights are combined, the sum of the two is the result. If the two coloured lights be complementary to each other, white light is produced. But if two complementary coloured dyes, paints, or glasses be combined, a grey is produced ; or if the colours be sufficiently strong a black is the result (see dyed specimen No. 3 at end). All the coloured rays transmitted through the one are absorbed or quenched by the other, as we have already seen in Chapter IV., Fig. 15 (see also the dyed specimens on Plate I. at end of book). Each colour subtracts from the other the rays which it does not itself transmit. It is the absorption of certain coloured rays with the reflection of others that produces the innumerable shades to be found in nature and art. The two methods are sometimes termed " additive " and " subtractive."

§ 43. The various methods of mixing colours employed by the physicist, i.e. by rotating coloured discs, superimposing by reflection one colour upon another, or casting, by means of a lantern, coloured lights upon a white screen, etc., are all interesting from the scientific point of view, but of little service to the mixer of ordinary everyday colours such as paints and dyes. A few examples might be given to illustrate this. Thus, if a deep shade of blue, dyed with

acid violet 7 B, and an orange yellow be mixed together in the dye-bath, a very deep maroon, or even a black, is produced. But if the *light* from these two dyed colours, the blue and the orange, be combined together, the result is not a maroon, nor anything like it, but a light *pink*, approaching almost to a magenta tint. The greater the portion of the blue light, the pinker the combined hue.

One of the simplest and oldest methods of combining the *lights* reflected from the surfaces of coloured objects is that devised by Lambert in 1760.[1] The two coloured materials are laid side by side upon a piece of black cloth placed upon a table. A piece of clean glass is placed upright between them, and, by looking through the glass at a certain angle,

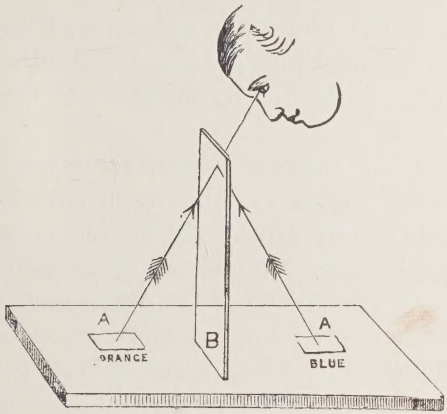


FIG. 25.—Mixing coloured lights by Lambert's method.
A A = colours to combine. B = sheet of glass.

the reflected images of the two coloured surfaces will be combined, one upon the other, as in the illustration. By slightly inclining the glass plate from the perpendicular position, either towards the one colour or the other, it is

[1] Johann Heinrich Lambert (1728–1777), mathematician, born at Mülhausen, in Alsace, was the first to show how to scientifically measure the intensity of light in his *Photometria*, 1760.

possible to strengthen or reduce the proportion of the coloured light.

This is a simple and instructive experiment which every colour student may profitably perform for himself. In the example we have just described, when the light from the orange predominated over that of the blue, a greyish pink was produced, while if the blue predominated it gave a light violet pink. If, in the same manner, the light from a piece of cloth, dyed an emerald green, be combined with the light from a bright eosine, or rhodamine pink, a greyish-white is produced, which truly represents the effect of the combination of complementary coloured lights. If, however, a piece of material be dyed in the dye-bath with rhodamine pink and a bright green, a series of reddish browns or russets is obtained if the pink be in excess, or, if the green predominates, a series of blue-greys is the result. This might readily be guessed by the examination of their combined absorption spectra.

Complementary coloured *lights*, therefore, when combined, produced *whiteness* ; while complementary *dyes* and pigments produce *blackness*. By mixing blue and yellow lights a greyish-white is produced, which is in accordance with the facts just mentioned ; whereas in dyeing and painting, as everyone knows, a green colour is the result of their combination (see Figs. 3 and 4, Plate II.). We have learned in Chapter IV. the correct interpretation of such absorption phenomena.

In the following table are a few examples showing the different effects produced by mixing colours : (1) by the philosophers' method, by the rapid rotation of the coloured discs, and (2) by the dyers' and painters' method (see also Plate II.). The colours chosen are, as near as possible, representative colours, dyed upon wool or silk fabric.

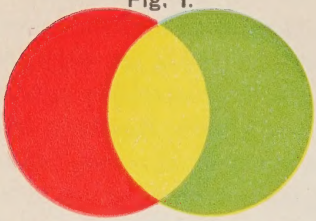
A sufficient number of examples have been given to

ADDITIVE SUBTRACTIVE

Plate II.

Coloured Lights combined.

Fig. 1.



Dyes and Pigments combined.

Fig. 2.

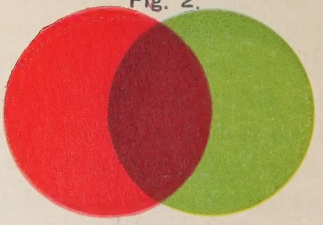


Fig. 3.

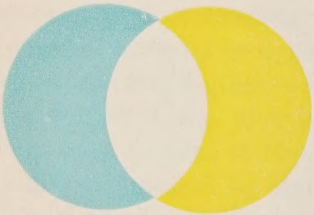


Fig. 4.

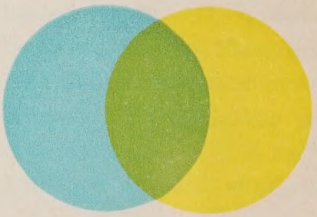


Fig. 5.

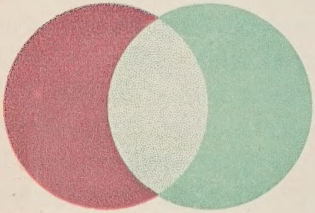


Fig. 6.

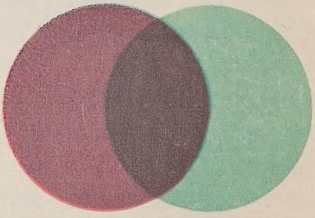
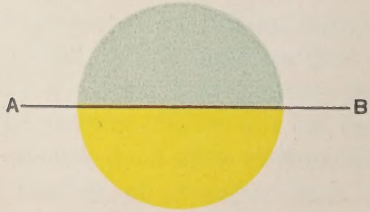


Fig. 7.



To show the very different results produced by mixing Coloured Lights *versus* Dyes.

[*See* Chapter V.]

illustrate how the mixing of colours by the rapid rotation, or any other similar method employed by the physicist, is altogether unsuitable for the dyer, printer, artist, and all those engaged in the *practical* mixing of colours.

Plate II. illustrates the different results obtained by mixing coloured *lights* in comparison with that of *dyes* and pigments. This is also beautifully shown in our Frontispiece.

Red and green lights combine, as in No. 1, to form the sensation of yellow, while in dyeing and ordinary colour mixing a dull maroon or even a black is the result, as in No. 2.

Blue and yellow lights when combined produce white light 3—indistinguishable by the naked eye from the ordinary white daylight composed of all the spectrum colours. The spectroscope or prism, however, would reveal the difference.

Blue and yellow dyes, as we already know, produce, not white, but green, as in No. 4.

Colours mixed.	*Shades produced by dyeing.*	*Shades produced by rotation.*
Nahpthol yellow Victoria blue	Fine green.	Grey.
2 R scarlet Azure-blue	Maroon or black.	Reddish-purple tint.
Red Yellow-green	Terra-cotta shade.	Very pale pink.
Acid magenta Green	Dark red, or a violet.	Pale reddish-pink.
Red, deep shades Green	Black.	Grey.
Methyl violet Yellow-green	Dark plum shade.	White.
Yellow Methyl violet	From dull sage to a claret.	Yellowish-white.
Orange Deep violet	Dull crimson.	Light bluish-pink.
Blue Red	Deep red or maroon.	Violet-purple.
Purple Green	Dark green or sage.	Grey.

Nos. 5 and 6 show the difference between mixing pink and sea-green lights, and pink and sea-green dyes. In the former a faint bluish-pink tint is obtained, approaching almost to a white; while in dyeing, a beautiful shade of violet is the result. By combining the blue and yellow of No. 7 by Lambert's method (see Fig. 25) a greyish-white is produced, instead of a green.

In Fig. 2 of Frontispiece is shown the results of combining coloured lights of the three primary sensations of red, green, and blue. The red and green produce yellow, green and blue produce light sea-green, while red and blue produce a light pink. Where all the three sensations combine together, as in the centre of the diagram, white light is produced.

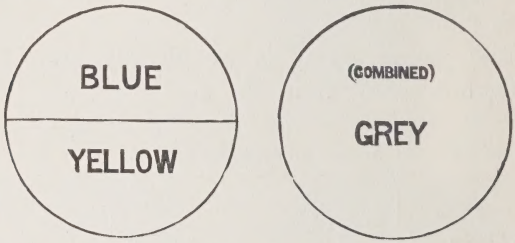


FIG. 26.—Diagram illustrating Lambert's method.

For many years it was supposed that the results given by these two methods of colour-mixing, namely, by dyeing or painting, and by rotation, were identical; but, after a few experiments such as we have stated, it is seen that they are by no means the same. Lambert, in his famous investigations on colour about 1760, found that by combining blue and yellow lights, in the manner shown in Fig. 25, he obtained, not a green, but a *white*.

If we take a cardboard disc like Fig. 26, one-half of which is painted with ultramarine blue and the other with a pale chrome yellow as shown in No. 7 of coloured Plate II.,

and rotate it quickly before the eye, so that the blue and yellow are mingled upon the retina, there is produced, not a green, but a grey, slightly tinged with yellow. If the proportions of the blue and yellow be carefully adjusted, it is possible to remove this tinge of yellow and obtain a pure neutral grey. This same result may be found by combining the blue and yellow by means of the Lambert method, i.e. by placing a sheet of clean plate glass on the line AB of Fig. 7, when, by looking through the glass in a manner similar to that shown in Fig. 25, the image of the yellow overlaps that of the blue and a dull yellowish-grey is seen as the result of their combination. By slightly tilting the glass from the vertical position, the proportion of the yellow or the blue light may be varied until a fairly good grey tint is obtained. These simple experiments, therefore, show that the Brewster theory of yellow and blue producing a green does not hold good so far as coloured lights are concerned. If, instead of the blue and yellow pigments in this experiment, we used coloured *lights*, or the pure spectrum colours, thrown on a screen, the result would be a pure white light instead of a dull grey.

As this little manual is intended for dyers, calico printers, and others who must adopt the practical primaries, red, yellow, and blue, we need not enter further into the various methods employed by the physicist in mixing coloured lights, but would refer the reader to the larger works on colour physics.[1]

§ 44. In mingling two coloured pigments or dye solutions, the resultant colour is due, as we have already seen, to the double absorption or subtraction which the light has undergone. What remains over is the coloured light which

[1] I would specially recommend to the student *Colour Measurement and Mixture*, by Captain Abney. See also *Colour and its Applications*, by Luckiesh.

emerges unabsorbed by either of the mixed colours. For several reasons it is necessary for the dyer and colour mixer to keep to the old primaries of red, yellow, and blue, which, with the addition of black and white, produce all the colour sensations the eye is capable of perceiving. The black and grey can be produced by mixing these three practical primaries together. By combining these so-called primary colours we get the **Secondary Colours,** orange, green, and violet, thus :

Red + yellow produces orange.
Yellow + blue ,, green.
Blue + red ,, violet or purple.
(See Fig. 1, coloured Frontispiece, also Fig. 27, p. 77)

The dyer, by varying the proportions of the primaries, can obtain innumerable gradations of hue ; thus, in the case of orange, a series can be made ranging from an orange-red on the one hand to an orange-yellow on the other, thus :

Secondary Colours.

3 Red + yellow = orange-red.
2 Red + yellow = red-orange.
Red + yellow = orange.
Red + 2 yellow = yellow-orange.
Red + 3 yellow = orange-yellow.

The production of the secondary colours by the combination of two of the primaries is seen at Fig. 27, page 77. In the same way a great variety of greens, ranging from greenish-yellow to a blue-green, and of violets from a blue-violet to a red or purple hue, can be produced by varying the proportions of the two primaries.

TERTIARY COLOURS

§ 45. **Tertiary Colours.**—What are termed tertiary shades are those produced by the combination of all the three primaries. The third primary colour, however, does not produce a new *hue,* but merely plays the part of dulling or saddening the other two by forming a certain amount of grey

or black by its combination ; hence the many indescribable shades used in the arts, and known as tertiaries, are simply the primary or secondary hues dulled with grey.

As seen in Fig. 27, green and orange combine to form olive or *citrine*. Orange and violet produce a reddish-brown or *russet* ; while green and violet give a blue-grey or a *slate* shade. But, if we examine carefully the formation of these so-called tertiary shades, bearing in mind that the three primaries together produce grey or black, it will be found that they are nothing more than " broken," or dulled tones, of the primaries and secondaries.

Let the symbols, R, Y, B stand for red, yellow, and blue, and we may analyse the tertiary shades as follows :

2 Y + R + B = Y + grey = yellow-grey or citrine.
Y + 2 R + B = R + grey = red-grey or russet.
Y + R + 2 B = B + grey = blue-grey or slate.

Thus the three shades—citrine or olive, russet and slate—are simply the three primaries, yellow, red, and blue, flattened with a quantity of grey.

There are six normal tertiary shades altogether, the other three (sage, buff, and plum) being produced by an excess of two primaries, thus forming dulled tones of the secondaries, green, orange, and violet. These may be represented as follows :

2 Y + R + 2 B = Y + B + grey = green-grey or sage.
2 Y + 2 R + B = Y + R + grey = orange-grey or terra-cotta.
Y + 2 R + 2 B = R + B + grey = violet-grey or plum.

From the above it will be observed that the more colours there are in a mixture the duller or sadder is the colour produced, as a greater quantity of black (caused by absorption) is formed by their combination. This forms the one great difference between the mixing of coloured *lights* and the mixing of dyes and paints.

In mixing coloured lights the resultant hues produced have the combined brightness or luminosity of the

constituents ; while, in mixing dyes, the resulting colour is much duller because of the increased absorption of the coloured rays which has taken place.

For example, if violet and yellowish-green lights be combined, a white is produced, having the combined brightness of both of these lights ; while in dyeing and painting, by mixing violet with a greenish-yellow a deep plum shade is produced, as the eye receives only those rays which have escaped the absorptive action of both the violet and the yellow-green. In the former case the result of the mixture is brighter than either of its constituents ; in the latter case it is duller than either, from its being largely mixed with grey due to absorption (see also § 43).

§ 46. In the dyed specimens to be found at the end of the book are several soft tertiary shades prepared by the admixture of the three dyestuffs—metanil yellow, carmoisine WS, and indigo carmine X. Where the yellow is in excess a shade of yellow-brown or old gold is produced, as at No. 10 ; but, if the blue be increased to form a greater proportion of grey, then a sadder or flatter shade is formed, i.e. a dark rich brown as seen at No. 6. If the blue and yellow —producing a green—be in excess, then a sad green, or what is termed a sage, is the result, as at No. 11. It is seldom that two complementary dyestuffs—unless they be very strong and concentrated—can completely absorb all coloured rays when they are combined : yet in dyed Pattern Plate I. at the end we have a good example showing that when carmoisine WS and acid green G are combined together, total absorption of light or a black is produced, as shown in No. 3 of dyed patterns.

If the proportions of the three dyestuffs already mentioned, i.e. metanil yellow, carmoisine WS, and indigo carmine X, be carefully adjusted so that neither of them predominates in the slightest degree to form a tertiary

shade, then the result is a pure, neutral grey, such as we have at Nos. 7, 8, 9 of the dyed patterns. These are beautiful examples of neutral greys, produced by the careful balancing of the three primaries, yellow, red, and blue. The proportions of dyestuffs employed in dyeing each shade are also given.

§ 47. Before proceeding to study systematically the various phenomena produced by mixing colours, it may be well to understand clearly some important points in regard to the correct use of colour terms. Much confusion often arises from the slack, indefinite way in which colours are sometimes described.

COLOUR TERMINOLOGY

Colour Constants.—The first characteristics to be considered in relation to a colour are three in number—namely, its *Hue*, its *Purity*, and its *Brightness*. These are generally termed the colour constants.

1. *Hue.*—The hue of a colour is that which is generally understood by the term *colour*, such as yellow, green, purple, blue, etc. The excessive predominance of one or two of the simple colours over the rest gives the hue to a colour, and the greater that predominance, the stronger will be the hue. This is really the first characteristic of a colour demanding consideration, and from it we endeavour to *name* the colour. In mixing one colour with another the original colour must always predominate, otherwise it will become a hue of the colour which has been added. Thus in mixing red and blue together to produce violet or purple, if the red be in excess the result will be a violet of a *red hue* ; but if the blue be in excess, then a violet of a *blue hue* is produced. It is easy to remember the series of hues, when we bear in mind the various gradations of hue present in the spectrum or the rainbow—red, orange, yellow, green, blue, and violet.

Thus it is more correct, in describing a reddish-yellow, to

speak of it as a yellow of a reddish hue than to say a yellow of a red *shade*, though this expression is very generally used in commerce and among dyers and colourists. The term *shade*, as we shall see presently, signifies in its correct sense an admixture of grey or black. It is likewise better to describe reddish blues and violets as being of a red hue. It is wrong to employ the term *tint* instead of hue, as this term implies an admixture with white, or reduction. Thus we would not describe a greenish-blue as a blue of a green tint, or a yellow of an orange hue as having an orange tint.

Cast.—This term is often employed to denote the distinctive hue of a colour. Thus we may describe a red as being of a bluish cast, or a blue having a green cast, meaning its prevailing tendency of hue.

2. *Purity.*—By the purity of a colour is meant its freedom from admixture with white light, or with any other colour. The purest colours, and therefore the standard of purity, are those of the spectrum obtained by passing sunlight through the prism, as represented in Fig. 2 (see § 16). When comparing ordinary colours, such as pigments or dyed materials, with certain portions of the spectrum, it will be found that, though they correspond fairly well in hue to the spectrum colour, there is a want of depth and richness, which makes all such coloured objects appear pale before the pure colours of the spectrum. This is due to the quantity of white light reflected from the surface of all pigments and dyed materials. None of the ordinary colours can match the hues of the spectrum for purity. A pure colour is often termed *saturated*. But it must be remembered that a pure colour is not necessarily a bright or a rich colour, for there are some parts of the spectrum where the colours, though perfectly pure, are not bright. Colours which appear pure to the eye may nevertheless reflect many differently coloured rays. We have already learned (§ 25) that yellow, for

example, reflects not yellow rays merely, but a large amount of red, orange, and green. The beautiful aniline blues, which appear, perhaps, quite pure to the unaided eye, reflect, as a rule, a considerable amount of red, green, and violet light. It is indeed very seldom that a pure monochromatic colour is found, except when the colour solution is strong, or when dyed a deep, full colour on some rich-lustred fibre like silk. No ordinary pigment or dyestuff is perfectly pure coloured or monochromatic.

3. *Brightness or Luminosity.*—This is the third colour constant, or feature of importance, in colour examination, and is distinguished by the total amount of light which is reflected from the colour to the eye. It is also described as the "clearness" of a colour. By various scientific methods it is possible to ascertain the relative degrees of luminosity possessed by the spectrum colours, and it is found that the most luminous colour is orange-yellow; while the least luminous—as might naturally be supposed—is violet. Between these two extremes there are all intermediate degrees of brightness. The following colours are (according to Prof. Rood) tabulated in a descending ratio of luminosity:

1.	Orange-yellow = most luminous	7,000
2.	Orange	6,000
3.	Greenish-yellow to green	3,000
4.	Orange-red	2,000
5.	Blue-green, Cyan blue, Red (cherry) — Equal in luminosity	1,000
6.	Pure red, Blue — " "	400
7.	Ultramarine blue	90
8.	Dark red	80
9.	Blue-violet	30
10.	Violet = least luminous	13

Having now considered the three distinguishing features of colour, or the constants, i.e. (1) hue or colour proper; (2) purity, or freedom from white or other coloured light; and

(3) brightness or luminosity, we may now consider the proper use of a few of the commoner colour terms.

§ 48. TINTS AND SHADES

Tint.—The addition of white in regular quantities to a colour produces a *reduced* scale, or what are termed *tints* of the normal hue. In dyeing or calico printing the admixture of white is, of course, an impossibility, but if the colours be dyed on a white material the gradual diminution of the quantity of the dyestuff equals the same thing.

It is said that 1 part of white light added to 360 parts of coloured light produces a very slightly paler tint that can be distinguished by the practised eye, and it is here that the skill of the experienced colourist is shown. An eye trained to distinguish the nicest variations in the hue or the tint of a colour can see decided differences in two colours which, to an ordinary person, appear as identical.

It is an important point to remember that in reducing a colour to form a good series of tints there should be no variation in the hue of the colour. It is often noticed by textile colourists that in reducing certain colours into a scale of tints, the normal colour changes slightly in hue as it becomes weakened, thus giving to its lightest tint a slightly different "cast." In such a case it is often necessary to add a minute quantity of some other colour ingredient in order to maintain a regular gradation of hue.

For example, in reducing a scarlet to form a salmon tint, it may be found to go off into a pink tinge, and requires the addition of a slight touch of yellow to make it right. Yellows, in being reduced into tints, often go off into a greenish, or a sulphur yellow hue, or become buffy or reddish. Hence it is often necessary for colourists and dyers to make trials in reducing their dyes to see how they go.

It is very seldom that in reducing blacks we get good

greys, as some go purplish, others go reddish, while some reduce to a greenish tone, and hence it is necessary to add some other colouring matter to neutralise this predominant hue and form a pure grey. The Chinese colourists have long been well aware of this, and the secret of their " Chinese ink " is that even when it is reduced with white to form the lightest tints it still preserves its fine neutral grey tone.

In reducing all classes of colours—yellows, greens, blues, etc.—to form tints, the colourist must often find that they require the aid of another colouring matter to keep them on the proper scale. The cause of this gradual difference in hue is owing to the natural impurity of all ordinary dyes and pigments and to the property of selective absorption, or dichroism, already considered in Chapter IV. (see § 39). For tints which harmonise or are complementary see Fig. 29.

Shades.—The addition of black in regular quantities to a colour produces a *darkened* scale, or what is termed a *shade* of the normal colour. The term " shade " in the ordinary colour nomenclature of commerce is greatly misapplied, and we hear it constantly used where the word *hue* is more correct. Thus a clear yellow is often described as a " pure *shade* " of yellow, which is a misuse of the word. A bright and pure hue cannot be correctly termed a " shade," which necessarily implies a greyness or dulness. The word " shade " is a very general one, and includes all the many tertiary hues, which are simply the primary and secondary colours flattened with grey or black, and all the variety of so-called mode or fashionable colours. These are sometimes described as " shades of tints."

On the next page are a few of the fundamental colours with their corresponding tints and shades.

The many so-called " tertiary hues" with their tints and shades are of endless variety, and we have only to examine

the many beautiful pattern cards issued by the various colour-manufacturing firms to realise the immense number of shades, all differing more or less from each other.

§ 49. **SCALE OF COLOUR.**—A scale is the collection, or series, of gradating tones of a given colour. There are as many scales as there are hues. Such a series of colours is sometimes termed " stepping " shades.

Besides the *reduced* scale of tints and the *darkened* scale of shades there is sometimes termed a dulled scale of broken tints, i.e. normal hues mixed with progressive proportions of *grey*. These are generally termed " broken hues," and are merely dulled tones of the primaries and secondaries.

Tones.—The series of gradations of a hue, weakened

Fundamental colours.	*Tints (admixture with white).*	*Shades (admixture with black).*
Red (bluish) . .	Pink.	Maroon.
Vermilion . .	Yellow-pink.	Russet.
Scarlet (orangy-red)	Salmon-buff.	Brown.
Orange-red . .	Salmon-buff	Yellow-brown.
Orange . . .	Salmon. [yellowish.	Terra-cotta.
Yellow-orange. .	Amber.	Yellowish-terra-cotta.
Orange-yellow. .	Cream.	Old gold.
Yellow . . .	Lemon or sulphur.	Citrine.
Yellow-green . .	Straw.	Olive.
Emerald green .	Pea green.	Sage.
Bluish-green . .	Sea green.	Myrtle.
Turquoise . .	Pale turquoise.	Dull indigo.
Cobalt, blue, or indigo	Pale blue.	Slate, to a deep navy blue.
Purplish-blue . .	Azure.	Blue-slate.
Mauve or bluish-purple	Lavender.	Purply-slate.
Violet . . .	Amethyst or light	Puce, or purplish-black.
Reddish-purple .	Heliotrope. [violet.	Plum, or maroon.
Bluish-red or crimson .	Pink (bluish).	Claret, or garnet.

For finding the various tints and shades which harmonise well with each other, or what are termed " complementary," consult Figs. 29 and 30.

by the addition of white, or shaded by the addition of black, may be termed tones of that colour, but they

may also be described as tints and shades, as already given in § 48.

Sombre and sad colours are those belonging to the blue and violet class, and the broken tones of the luminous colours.

§ 50. **COMPLEMENTARY COLOURS.**—It has already been stated that certain pairs of coloured lights, when combined, produce white light. These colours are said to be complementary to each other. The following pairs of colours are complementaries :

Red	and	blue-green.
Orange-red	,,	green-blue.
Orange	,,	azure-blue.
Yellow	,,	violet-blue.
Green-yellow	,,	violet.
Yellowish-green	,,	purple-violet.
Green	,,	red-violet or purple.

With the Brewster, or practical, theory of primaries—red, yellow, and blue—which the dyer and artist adopt, the combination of two complementary hues produces grey or black, as the one colour absorbs all the rays of its complementary, and darkness is the result. It may be simply stated that the colour which is *absent* from a mixed colour is the complementary. Thus :

Orange	(composed of red and yellow)		is the	complementary	of	blue.
Green	(,,	yellow and blue)	,,	,,	,,	red.
Violet	(,,	blue and red)	,,	,,	,,	yellow.
Citrine	(,,	green and orange)	,,	,,	,,	violet.
Slate	(,,	green and violet)	,,	,,	,,	orange.
Russet	(,,	violet and orange)		,,	,,	green.

For a more extensive series of complementary hues see Figs. 29 and 30.

The complementary of a primary colour is therefore the secondary composed of the other two primaries.

A simple method of illustrating the primary, secondary, and tertiary hues and their complementaries is seen in diagram, Fig. 27. In the first are shown the three primaries,

red, yellow, and blue, combining to form the three secondary hues, orange, green, and violet.

It will be observed that—

Red and yellow when combined produce orange,
Yellow and blue ,, ,, green,
Blue and red ,, ,, violet;

while the three primaries combined produce that absorption of all the coloured rays of light which represents black in the centre.

In this diagram the complementary colours are found opposite each other. Thus:

Red is opposite to its complementary, green,
Yellow ,, ,, ,, violet,
Blue ,, ,, ,, orange.

In the same manner the second diagram illustrates the formation of the three tertiary shades by the combination of the secondaries, orange, green, and violet.

In making pure tones of the secondary colours by the admixture of primaries, it is necessary to select those primaries *having a tendency of hue towards the desired secondary*; otherwise very poor and dull colours will be the result. To make a pure green, for example, the yellow and the blue must *not* be of a reddish tone, but be somewhat inclined to be greenish.

The presence of a little red along with yellow and blue produces a quantity of *grey*, which mars the purity and brightness of the green. This explains the reason why, in dyeing with a mixture of yellow and an alkali blue of a violet cast, a citrine shade is produced instead of a good green. A very interesting example of this may be found in the following experiment.

Take two blues, one of them being decidedly greenish, say wool green S, and the other victoria blue, and add to each a proportion of a golden yellow, like fast yellow, or

formazone. The difference in the resultant greens will be astonishing—far more than anyone would have expected. The colour dyed with the wool green will be a strong decided green, while the other will be a brownish-olive or khaki colour.

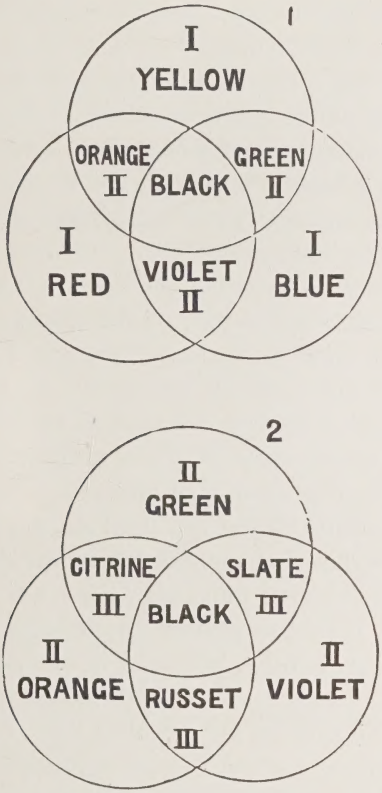


FIG. 27.—Diagrams showing the formation of secondary and tertiary colours from the three primaries, red, yellow, and blue.

Orange and green produce citrine.
Green and violet ,, slate.
Violet and orange ,, russet.
Orange is opposite its complementary, slate.
Green ,, ,, ,, russet.
Violet ,, ,, ,, citrine.

Even an experienced colourist was astonished at the results obtained, until examination of the dyestuffs with the spectroscope revealed the cause.

The yellow absorbed all the violet end of the spectrum up to the blue-green, namely violet, blue-violet, blue, and blue-green, and transmitted freely the red, orange-yellow, yellow-green, and green rays.

The wool green absorbs strongly the red part of the spectrum, as far as the D line in yellow, and freely transmits the green, blue, and violet rays. It is thus seen that by combining the golden yellow with the wool green, only the yellow-green and green rays are transmitted, while all other parts of the spectrum are absorbed more or less.

When we come to examine the spectrum of the victoria blue we find that the red part of the spectrum is not fully absorbed, but a good proportion of red and orange rays are transmitted, along with all the green, blue, and violet. When such a blue as victoria blue is combined with the yellow, the transmitted light consists of the green, along with a reduced proportion of orange and red. These rays combining on the retina of the eye produce the sensation of a dulled yellow or khaki shade. A somewhat similar instance is illustrated in coloured Plate III., Figs. 1 and 2. But this subject, which is of the utmost importance to every dyer and colour mixer, is fully discussed in our next chapter on Colour Mixing. For the effects produced by mixing suitable and unsuitable primaries see coloured Plate III.

§ 51. A knowledge of the various complementary colours is of great importance to every dyer and colourist, as it enables him to produce the finest effects of colour harmony and contrast. It is also of much service in studying the various phenomena observed in matching colours.

A ready method of finding the harmonising complementary of any given colour is found in the arrangement termed

the "chromatic circle," which has already been introduced in Figs. 13 and 17. Though simple, it is a most convenient device for studying the chief varieties of colour and their mutual relations to each other. Fig. 28 represents the chromatic circle in its simplest form. At equal distances around the circumference are placed the three ordinary primaries—red, yellow, and blue—and their complementary secondaries—green, violet, and orange—are found exactly opposite them on the circumference. The colour at one end of any of the diameters is the complementary to that found at the other end. A more extended chromatic circle is seen in Fig. 29, where sixteen different hues have been selected, forming eight pairs of complementaries. The inner circle represents the *tints* obtained from the various colours by reducing them with white.

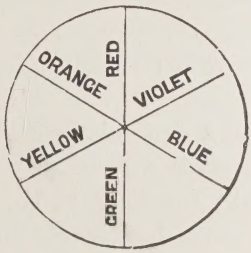


FIG. 28.—Chromatic circle.

In the table below is given the list of the corresponding complementaries which are found opposite each other in the outer chromatic circle.

Pairs of Complementaries.

Scarlet carmine	and	emerald green.
Crimson	,,	yellowish-green.
Violet or purple	,,	yellow.
Blue-violet	,,	orange-yellow.
Purplish-blue	,,	yellowish-orange.
Cobalt blue	,,	orange.
Turquoise	,,	orange-red.
Blue-green	,,	vermilion red.

In the same manner the complementary tints are as follows (see inner circle, Fig. 29) :

Pairs of Complementaries (Tints).

Buff	and	pea green.
Pink	,,	straw.
Heliotrope-violet	,,	lemon.
Lavender	,,	cream.
Azure	,,	amber.
Pale blue	,,	salmon.
Pale turquoise	,,	salmon-buff.
Sea green	,,	yellowish-pink.

When these complementary colours or dyes are combined, either on the palette, in the colour-tub, or in the dye-bath, darkness or a grey is produced. If the colours be sufficiently strong, a black will be the result. Owing to the natural impurities always present in ordinary colours, however, it is seldom that two dyes, unless in a concentrated state, produce a good black, as the slightest predominance of one of the colour constituents gives to the result a certain cast or hue which takes it from a pure grey or black.

Archil, which is of a deep claret colour, when combined with indigo extract gives a good dense black, as the one colour totally absorbs the light of the other. Carmoisine WS and acid green G produce, when mixed, a fair black as seen in dyed pattern No. 3, and the beautiful pink of rhodamine, when combined with a yellow-green, gives shades of bronzy-grey. If the colouring matters be mixed in such a proportion that one colour predominates over another, then the resulting colour will have the hue of the colour in excess. Thus, if scarlet and green be mixed so that an excess of green is used, a sage shade is produced ; while, if the scarlet be the predominating colour, a brown or russet is the result.

In our next illustration, Fig. 30, we have a chromatic circle similar to Fig. 29 ; but the inner circle here

represents the effect produced by combining the complementaries named at the opposite side of the outer circle.

It will be observed that all these tertiary hues are, as we have already learned (see § 45), merely primary and secondary colours saddened with varying proportions of grey or black.

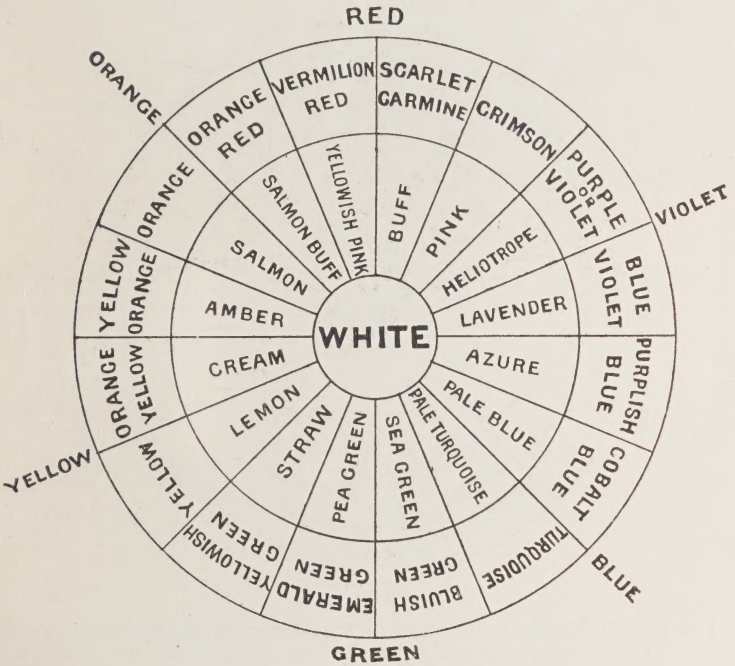


FIG. 29.—The inner circle represents the effects of adding white (tints) to the saturated colours named in the outer circle. The tints opposite each other are complementaries.

The results of the mixing of the two complementaries may be represented in the following table, in which the colour which predominates in the mixture is printed in larger type.

Thus **scarlet** + emerald green = brown, may be taken to represent that a mixture of scarlet and green, with scarlet in excess, produces a brown; while scarlet + **emerald green** = sage colour, means an excess of green gives to the mixture a sage hue. The following list of

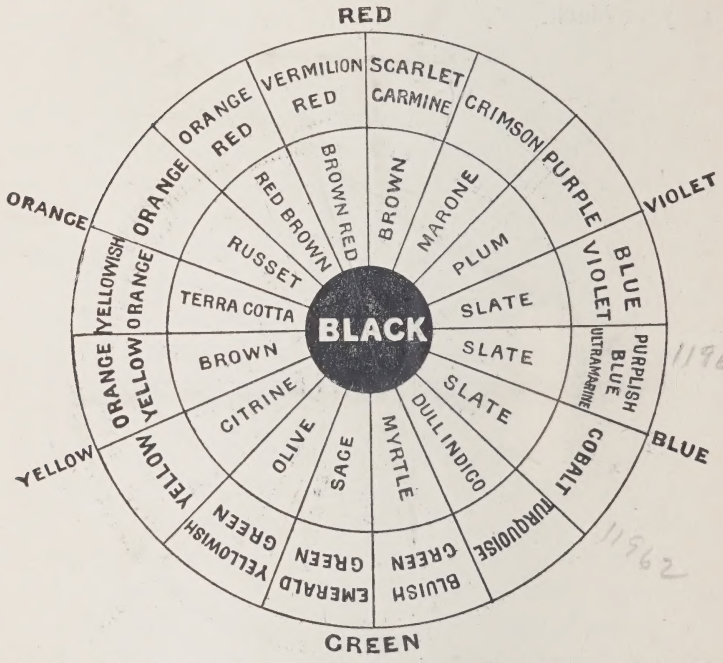


FIG. 30.—The inner circle represents the effect produced by combining the complementaries named at the opposite sides of the outer ring. They are shades of the normal colours, similar to those produced by the addition of grey or black.

colours, obtained by admixture, will be found in the chromatic circle, Fig. 30.

The mixed hues in the inner circle are complementary to their opposites in a similar manner to the outer colours already described.

Shades produced by admixture of complementaries.

Colour in excess.		Colour deficient.		Result of admixture.
CRIMSON	+	Yellow-green	=	Maroon.
YELLOW-GREEN	+	Crimson	=	Olive.
PURPLE	+	Yellow	=	Plum.
YELLOW	+	Purple	=	Citrine or olive.
BLUE	+	Orange	=	Slate.
ORANGE	+	Blue	=	Russet.
TURQUOISE	+	Orange-red	=	Dull indigo.
ORANGE-RED	+	Turquoise	=	Red-brown.
BLUE-GREEN	+	Vermilion red	=	Myrtle green.
VERMILION RED	+	Blue-green	=	Brown-red.

This brings us to the subject of colour mixing, to be more fully studied in the next chapter.

CHAPTER VI

COLOUR MIXING

MIXING QUALITIES OF COLOURS—PURE AND IMPURE GREEN, ORANGE, AND VIOLET—LARGE VARIETY OF SHADES FROM FEW COLOURS—CONSIDERATION OF THE PRACTICAL PRIMARIES, RED, YELLOW, BLUE.

§ 52. ONE of the first duties of the colour chemist and the dyer when testing a colouring matter is to examine what we might term its mixing qualities, and learn if it is suitable for producing good colours by admixture with others. It is well known to colour mixers that two apparently similar blues, when mixed with equal proportions of yellow, may give two very different greens. Some reds and yellows are better fitted for giving a pure, good orange than others; and likewise some blues and reds give very poor violets compared with others. This is an important consideration to colour mixers, when they mix shades to produce certain desired effects.

The coloured Plate III. illustrates the different results obtained by mixing suitable and unsuitable colours.

In making a green from blue and yellow it must be remembered that neither of these component colours must contain any of the third primary red, as its presence gives rise to a corresponding absorption of the green rays—producing an amount of grey which dulls the green colour.

Green.—Thus No. 1 (Plate III.) shows how slightly reddish blues, like some of the alkali blues, azure or ultramarine blues, the reddish brands of victoria blue, etc., when

Fig. 1.

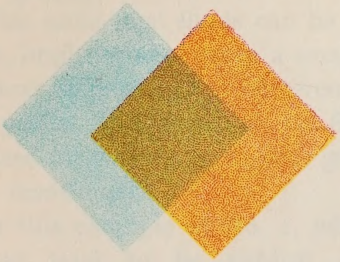


Fig. 2.

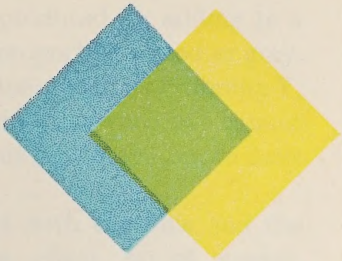


Fig. 3.

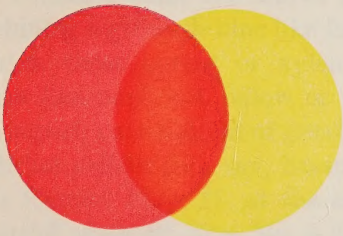


Fig. 4.

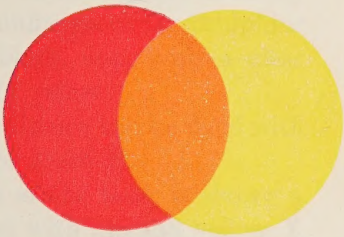


Fig. 5.

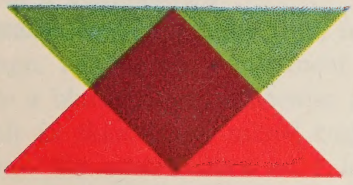
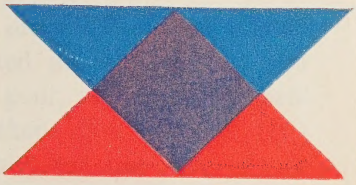


Fig. 6.



Showing how the purity and brilliancy of mixed Colours depend upon the suitability of their Component Colours.

[*See* Chapter VI.]

combined with a yellow, do not produce a bright green, but a green having a large amount of grey—namely, a sage. If the yellow be of an orange cast, the effect is still greater.

This same sage shade can be reproduced by adding to a pure, bright tone of green a small proportion of red or grey. Yellows of an orange or buttercup tone, such as citronine Y, azo yellow, Indian yellow, azo flavine, and such like cannot be used for making good, clear greens for the reason we have just mentioned.

In this example of No. 1, where both the blue and the yellow tend to be reddish, the effect is, of course, exaggerated ; but pure, bright greens can never be produced by mixing blues or yellows which show traces of red. No. 2 of coloured Plate III. shows the brilliant green made by combining a greenish blue like lissamine green B, disulphine blue B, those patent or xylene blues, etc., with a clear yellow like naphthol yellow or acid yellow.

A superb parrot green of great brilliancy can be dyed with naphthol yellow and, say, lissamine green B.

In Pattern Plate II. at the end of the book is shown a beautiful shade of olive No. 5 dyed with metanil yellow Y and indigo carmine X. As the yellow and the blue in this case are both of a reddish tone, an olive or citrine is obtained by their combination.

Orange.—In the same way, in order to produce a pure orange, neither the constituent red nor the yellow must have a bluish tinge ; otherwise a poor, muddy orange will result in their being mixed together. No. 3 (Plate III.) shows the combination of a bluish red like magenta or carmoisine WS, cardinal or suchlike, with a yellow, producing, instead of an orange, a dull russet colour.

This is owing, as we have already stated, to the fact that the presence of the third primary (in this case blue) produces

a proportion of grey, which changes the orange into a broken tone, or a russet.

Exactly the same colour is obtained by adding a slight quantity of blue or of grey to a pure tone of orange.

No. 4 shows the production of a pure orange by combining a yellowish red or scarlet with a yellow devoid of any green cast. There being no third primary present, no absorption of the orange takes place, which means that no grey is present to destroy the purity of the orange.

The purest tones of orange are found in the aniline azo oranges, of which there is a large variety. They are pure and unmixed colours (*homogeneous*), and give a clearer and better tone of orange than we can get by admixture.

Violet.—Nos. 5 and 6 show the production of good and poor violets by the admixture of the different qualities of red and blue. To obtain a full, beautiful violet these two constituent colours should both tend toward the bluish cast. The result is a violet free from any appearance of grey (see No. 6).

Bluish-reds, such as carmoisine WS, cardinal 3 B, magenta, etc., when mixed with the reddish-toned alkali blues, produce very good violets.

Where a scarlet-red and a greenish-blue are combined, as in No. 5, a poor, dull violet is the result. The presence of the yellow primary in the scarlet-red produces absorption of the pure violet, and gives to the resultant violet a greyish dull effect.

Wool scarlet and disulphine B, or patent blue, for example, give very poor violets by admixture.

The purest tones of violet are obtained from the aniline colours, like Hofmann's violet, methyl or ethyl violets, etc. These are pure and homogeneous colours, and not produced by any admixture of red and blue.

The above are a few simple examples selected from many

others which might have been given had space permitted; but they are sufficient to show that when colours are mixed, the character of the resulting colour depends upon that of its constituent colours: also that when a certain colour effect is desired it is necessary to pay due attention to the properties of the individual colours constituting the mixture. The purity of a compound colour depends upon the suitability of its constituent colours.

§ 53. In studying the art of colour mixing, one of the most astonishing features which strikes us is the wonderful variety of different hues which can be obtained by the combination of only two or three fundamental colours. Although at the present day there are thousands of different dyestuffs, all differing from each other in colour and chemical properties, the skilled colour mixer requires only a few carefully selected colours to produce as wide a variety of effect as he desires. By knowing thoroughly the mixing or combining capabilities of his dyes, he may produce, with three simple dyestuffs, hundreds of different shades by simply varying the proportions of the three fundamental colours.

This fact may be readily observed in examining the many beautiful pattern cards issued by the various colour firms, where we find that a splendid selection of different shades, varying widely in appearance, can be obtained from two or three simple dyestuffs.

For example, from mixtures with a red like carmoisine WS, a blue like disulphine B, the xylene blues, or indigo carmine, and a yellow like metanil, or citronine Y, there can easily be obtained at least fifty or even a hundred totally different shades by combination, and from each of these shades again can be obtained a series of " stepping " shades by reducing into tints, or darkening into shades; so that several hundreds of different shades can readily be obtained from these three simple dyes. Between the stepping

shades of a series the experienced eye of the colourist can distinguish many other intermediate tones, so that the several hundred shades can be sub-divided into thousands.

A scale or gradating series of shades, from a deep, full colour to a light tint of the same colour is, of course, produced by varying the proportions of the dyestuffs used.

In the following table we have the proportions of a few simple dyestuffs, red, yellow, and blue, which produce in dyeing a wide range of useful shades.

Red. (Lissamine fast red.)	*Yellow.* (Lissamine fast yellow.)	*Blue.* (Durocyanine.)	(*Shade produced.*)
1	1	2	Stone drab.
1	—	2	Dull violet.
1	1	3	Deep slate.
—	1	1	Dull sea green.
½	2	2	Deep myrtle.
½	1	½	Khaki.
½	½	2	Blue slate.
½	1	—	Tangerine.
½	1	½	Bronze.
—	1	½	Bright green.
¼	1	½	Moss green.
¼	2	¼	Citrine.
½	1	1½	Soft sage.
½	1	3½	Pine green.
1	1	1	Brown drab.

From disulphine blue, carmoisine WS, and citronine Y, we obtain a wide range of shades. The weights of colour stuffs here given (grams) are for dyeing 100 lb. of wool.

Disulphine Blue.		*Carmoisine.*		*Citronine Y.*		*Result of Mixture.*
60 (grams)	+	30 (grams)	+	20 (grams)	=	Light slate grey.
100 ,,	+	300 ,,	+	300 ,,	=	Cinnamon brown.
500 ,,	+	220 ,,	+	60 ,,	=	Dark blue-grey.
20 ,,	+	30 ,,	+	100 ,,	=	Delicate olive shade
400 ,,	+	400 ,,	+	100 ,,	=	Dull purple.
50 ,,	+	150 ,,	+	110 ,,	=	Brown drab tint.
25 ,,	+	5 ,,	+	250 ,,	=	Light yellow-green.
75 ,,	+	15 ,,	+	509 ,,	=	Bright leaf green.
225 ,,	+	45 ,,	+	1 ,,	=	Deep olive.
25 ,,	+	150 ,,	+	— ,,	=	Heliotrope.
100 ,,	+	600 ,,	+	— ,,	=	Rich purple.
100 ,,	+	35 ,,	+	50 ,,	=	Delicate sea green.

Disulphine Blue.		*Carmoisine.*		*Citronine Y.*		*Result of Mixture.*
100	+	100	+	100	=	Soft grey.
400	+	450	+	400	=	Dark grey-sage.
400	+	150	+	400	=	Beautiful olive.
30	+	23	+	—	=	Delicate dove grey.
40	+	15	+	500	=	Rich yellow olive.

In the dyed Pattern Plates II., III., IV. at the end of the book we have a few beautiful shades produced with simply three colour ingredients, metanil yellow Y, carmoisine WS, and indigo carmine X. The weights given are for 100 lb. material dyed.

Plate.	*No.*	*Shade.*	*Dyed with*		
			Metanil Yellow Y.	*Carmoisine WS.*	*Indigo Carmine X.*
II.	5	Citrine	0.4 per cent.	per cent.	0.15 per cent.
II.	6	Rich brown	2.1 ,,	0.15 ,,	0.5 ,,
III.	7	Light grey	0.01 ,,	0.04 ,,	0.37 ,,
III.	8	Mid grey	0.045 ,,	0.10 ,,	1.0 ,,
III.	9	Dark grey	0.09 ,,	0.2 ,,	2.0 ,,
IV.	10	Gold-brown	0.08 ,,	2.0 ,,	0.2 ,,
IV.	11	Sage	0.23 ,,	0.03 ,,	0.5 ,,

We are now in a position to study intelligently the various absorption phenomena observed during the mixing of ordinary colours and dyes; and, in order to do so systematically, we had better consider them briefly in the following order:

1st. Primaries: red, yellow, blue.

2nd. Secondary colours: orange, green, purple or violet.

3rd. The large variety of hues termed the tertiaries, or sad shades.

Practical Primaries—Red, Yellow, Blue

§ 54. **Reds**

At the present day there is a large variety of red colouring matters at the command of the dyer and calico printer, ranging from bluish-reds, such as roccelline and azo rubine to orange-reds and scarlets. The pure red of the spectrum

lies in the locality of the Fraunhofer lines, A, B, C (see Fig. 7). Clerk Maxwell selects his sensation of pure red even beyond the line C towards D. Mercuric iodide is sometimes taken as a type of normal red, but it, unfortunately, changes its hue on exposure to light.

Many of the coal-tar reds, such as the various brands of scarlet, 3 R to 6 R, palatine, brilliant, and wool scarlets, when used in sufficient strength to dye a good, saturated colour, represent a fair monochromatic scarlet red. Cochineal red dyed with cochineal, oxalic acid, and tin crystals also gives a good bright scarlet.

Any of the above-mentioned aniline reds, dyed at the proportion of 3 lb. of colour to 100 lb. wool or cashmere cloth, will produce a splendid red, which, on examination with the pocket spectroscope (see Chapter III.), will be found to consist of red rays from the locality of the spectrum marked with the lines A, B, and C. A bluish class of reds, much stronger than the scarlets, are the fast reds or roccel-lines, of which there is a large variety sold under various different commercial names, such as rubidin, azo rubine, carmoisine, claret red, amaranth, etc., etc.

By viewing a solution of an aniline scarlet with the spectroscope, it is found to transmit almost a pure red, giving a spectrum similar to that of ruby glass, as seen in the illustration (Fig. 18).

§ 55. SCARLETS may be described as orange-reds, i.e. reds having no bluish cast. We can never speak of a scarlet of a *bluish* hue, as scarlet denotes a predominance of orange or yellow.

The locality of scarlet on the spectrum is about C$\frac{1}{2}$ D, or midway between the lines C in red and D in yellow.

The word vermilion now denotes a scarlet red,[1] but, in its

[1] The orange-red colour of cinnabar or mercuric sulphide is taken as the typical colour of vermilion.

original sense, it was more of a crimson hue, like a rose. For example, Spenser speaks of the "Vermeill red-like roses." Vermilion is derived from the Latin *vermes*, a worm, and originally meant the *kermes* insect or cochineal, from which we derive the words *crimson* and *carmine*; so that vermilion and crimson, though now considered quite different hues of red, were evidently the same colour originally. To the colourist the subject of colour nomenclature forms a most interesting study.

Formation of Scarlets. An interesting method showing the optical structure of reds and scarlets by admixture is by combining rhodamine pink and an aniline yellow, such as tartrazine or naphthol yellow, or the eosines with some of the azo oranges. Rhodamine and yellow, when mixed together in suitable proportion, give a fine scarlet. This is owing to the yellow absorbing the violet rays transmitted by the rhodamine pink, which leaves only the red and orange to be freely transmitted. This gives the sensation of a fine scarlet colour.

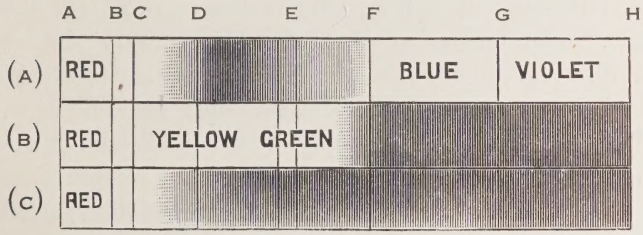


FIG. 31.—Showing the formation of a red by the combination of rhodamine (A) and naphthol yellow (B). The combined spectra (C) show transmission of the extreme red rays only.

This may be readily seen by examining the absorption spectra of the two dyes (Fig. 31). Thus (A) represents the absorption band of rhodamine, the shaded portion representing the locality in the spectrum where the coloured

rays are absorbed. It shows that red, orange, and orange-yellow are transmitted, and also the blue, blue-violet, and violet; while the yellow, yellow-green, and green are absorbed, i.e., the shaded portion from $C\frac{1}{2}$ D to F in the blue-green. Naphthol yellow, (B), on examination with the spectroscope, is found to absorb all the violet end of the spectrum. When rhodamine pink and yellow are combined, therefore, there is complete absorption from the extreme violet, through blue, green, and yellow, as far as orange; this leaves only the red and red-orange rays, A, B, C, to be transmitted, as seen in C, Fig. 31. This explains the production of reds and scarlets by the mixing of eosine pinks with orange or yellows. For an example exactly the opposite in effect, namely, where the *red* end of the spectrum of rhodamine is absorbed, leaving the violet and blue rays untouched, see the formation of a violet in § 66, Fig. 36.

Among sheepskin-rug dyers, where a boiling temperature cannot be employed to fully develop the aniline scarlet dyes, a very good red, ranging from a bluish tone to that of a scarlet, is made by combining acid magenta and an acid yellow. This dyes at a low temperature suitable for the skin dyer. The formation of this red is exactly similar to that already given with rhodamine pink. The acid magenta being a blue-red, reflects not only red but blue, violet-blue, and violet. This may be represented by the simple chromatic circle (Fig. 32).

The acid yellow transmits red, orange, yellow, and green, and absorbs the remainder of the spectrum (see 2).

Hence, when these two dyes are combined, as at 3 (Fig. 32), all the rays are absorbed except the red.

If the yellow be predominant a scarlet red is produced, and if the magenta be in excess a bluish tone of red is the result.

The same scarlet colour is obtained either from an orange

or a yellow; it does not matter which is used, as their only function is to absorb the violet end of the spectrum, the rhodamine itself absorbing sufficiently far towards the orange (see (A) Fig. 31).

The formation of a scarlet in this case is not simply a mixture of red and yellow making an orange-red, but is the result of the shutting off, or absorbing the blue and violet end of the spectrum of rhodamine, leaving the only remaining rays at the red end of the spectrum to be reflected.

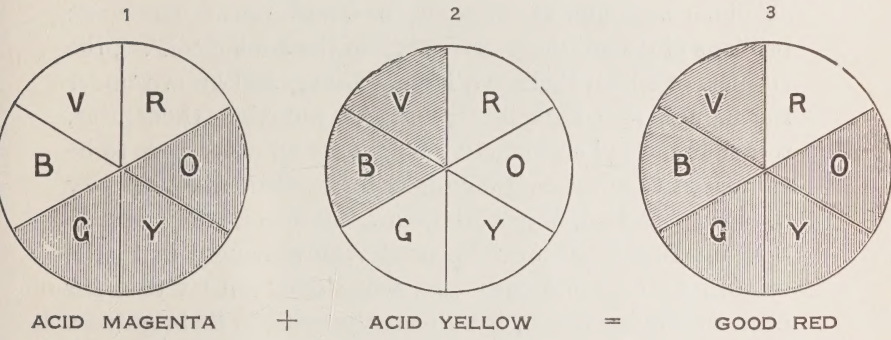


FIG. 32.—Showing the formation of a red by the combination of magenta and acid yellow as used in skin rug dyeing.

In the case of a scarlet, the red is transmitted and the violet end of the spectrum absorbed; while in the formation of a violet, the red end of the spectrum is absorbed and the violet end transmitted.

§ 56. BLUISH-REDS.—Crimson, claret, magenta, cardinal, amaranth, garnet, etc., etc., denote red colouring matters of a bluish hue. Some of the aniline dyes of this class, such as magenta and rhodamine pink, possess a purity and luminosity far exceeding any colour to be obtained by admixture.

The term purple is generally applied to a very red-blue

or a red-violet, which can be made by mixing Perkin's mauve with magenta. Purple, however, belongs more to the violet class of hues, and will be considered under the violets, § 64.

The number of tones of red that can be made by the dyer and colour mixer is infinite, as they range from scarlets or orange-reds to blue-reds or crimsons and purples; and their dull shades range from claret to maroon and puce.

§ 57. PINKS.—The beautiful class of rose colours known as pinks are diluted crimsons, or bluish-reds. The most brilliant pinks are those derived from the aniline colours, the eosines, of which there is a large variety, and known under the names, rose Bengal, erythrosine, phloxine, rhodamine, rosazine, methyl eosine, etc. There are no other dyes to be compared to these coal-tar pinks for brightness and purity of tone. Indeed, when they are unmixed, they are so brilliant that they must be used very sparingly in textile colouring. Silk and cashmere, when dyed with 1 to 2 per cent. of rhodamine B, is perfectly dazzling in its brightness of hue. When examining such colours the eye readily becomes fatigued, so that the colourist is unable to make an accurate judgment of the hues. To enable him to examine such bright colours with comfort he must resort to the use of glasses slightly tinted with green or blue, when such pinks assume the appearance of soft violets and purples, which can be carefully compared and examined at leisure. The absorption spectrum of such pinks, as seen in Fig. 22 (No. 1) and Fig. 24, is very sharp and decided. Where the absorption band of a colour is narrow and intense, the result is a pure and luminous colour. When mixed with other colours, greater absorption is produced, which tends, more or less, to make the resultant colour dull or less luminous.

When a yellowish-green, such as lissamine green B, wool green, or acid green, is combined with rhodamine pink, various soft shades of violet, deepening down to a grey or black, are produced, due to the increased absorption of the coloured rays.

A beautiful series of delicate tints of mauve, heliotrope and violet are obtained by the admixture of eosine pinks and some of the bluish aniline greens, like wool green, malachite, victoria or brilliant greens. The manner in which these are formed is the same as the violets (*q.v.*).

§ 58. Tints of Red.—When reds are reduced either with water, as in the dye-bath, or with paste, as in calico and carpet yarn printing, to form a series of tints, it is found that some go off bluish, while others reduce to a yellowish or buffy cast, and therefore require the addition of another colour to keep them on the right scale. Thus, if a series of reds gradating into pinks are to be made from some of the aniline reds, it is often necessary, in the third or fourth reduced tint, to add a small quantity of a bluish-pink to keep the series in harmony, if the red has a tendency to go yellowish. Many similar slight changes in hue are observed when reducing colouring matters to form a class of tints. This arises from the slight dichroic properties, or what is termed selective absorption, naturally present in nearly all dyes. For the cause of this dichroism see § 39, Chapter IV. Tints of a bluish-red are termed pinks, while those of an orange-red or a scarlet are termed salmon, buff, and flesh tints. *Shades* of red, i.e. red mixed with grey or black, form the class of colours termed claret, maroon, puce, etc.

§ 59. Yellow

It is a matter of some difficulty to locate exactly on the spectrum where the perfect representations of the various standard colours are to be found.

The locality assigned to yellow is generally a little beyond the Sodium Line D, more towards the green-yellow portion of the spectrum. The D line is in the midst of the orange-yellow (see Fig. 7).

Yellow is an important colour to the colourist; not simply because of its great brilliancy or luminosity, but because of its somewhat unique position in regard to the true theory of colour. As we have already stated, practical dyers and colourists accept the red, yellow, and blue theory of primary colours (Brewster theory) as the only applicable standard where ordinary dyes and colours are employed. A yellow cannot be produced by admixture of other colours, hence we call it a primary; but with the physicist, who adopts the Young-Helmholtz theory, yellow is considered a secondary colour, as it can be made by the combination of red and green lights (see Plate II., No. 1).

Yellows are found to range from those of a greenish cast to an orange-yellow; but those belonging to the former class, i.e. greenish or lemon-toned yellows, are considered the finest. Among the beautiful yellows of this description may be mentioned acid yellow, quinoline (or chinoline), naphthol, and tartrazine yellows. The beautiful, clear, greenish cast of the two latter dyes becomes evident when they are diluted. In their strong tones they are pure golden yellows.

Two yellows in their deep tones may match each other perfectly; but when diluted to form light tints of yellow, may give altogether different results: one tint may be of a greenish hue, while the other may have a reddish or buffy cast. This is owing, as we have already learned, to the property of selective absorption, or dichroism (see § 39) present in all dyes.

Yellows of a greenish hue make the purest and most brilliant greens by admixture with greenish blues. A bright green of superb quality may be dyed on silk or

wool with three parts quinoline and two parts victoria, malachite or brilliant greens. Such a green keeps its vivid beauty even in artificial light, and is used for dyeing billiard-table cloth.

Yellows of this greenish cast lose much of their beauty in a yellow light, and become pale and ineffective. If they are of a light tint, they cannot be distinguished from white.

Yellows, to look well in gas or lamplight, must belong to the orange or buttercup class of hue.

When yellow is mixed with a suitable proportion of pure grey, a soft, olive-green shade is produced, which, to the inexperienced colourist, appears as if it had been mixed with a quantity of green or blue.

Beautiful shades of olive and citrine are produced in this manner, which shows that they are simply dulled yellows, i.e. yellows having a quantity of grey in their composition. as already observed when studying the formulæ of these tertiary shades in § 45.

Olives dyed in this simple way match those dyed with a mixture of orange, yellow, and green or blue.

Several brands of aniline yellows have a reddish cast, or what might be termed buffy yellows, like azo flavine S, citronine Y, azo yellow, orange N, metanil, fast and brilliant yellows, etc. Such tones of yellow are suitable for making dull sage greens or citrines by admixture ; but they are too red to give clear, brilliant greens. This may be seen in Plate III, Nos. 1 and 2, and also in the dyed shade, No. 5, on Pattern Plate II at the end of the book, where metanil yellow and carmine X are combined.

The spectroscopic examination of a yellow—no matter how pure it may appear to the eye—affords a very good example, showing the compound nature of all our ordinary colours, like paints and dyes. Only the yellow of the spectrum consists of pure or homogeneous yellow light. A

solution of naphthol yellow in water, or a piece of silk dyed with this dye, present to the eye the impression of a pure yellow. But if we examine the yellow with the spectroscope as described in Chapter III (§ 24), we find that it contains not only yellow, but red, orange, green, and bluish-green, while the blue and violet rays are totally absorbed.

But the red and green rays go to form yellow, and the orange and green-blue are in such proportions that they combine to form *white* light within the eye; so that the colour we perceive is really composed of the yellow combined with a proportion of white light, giving to the colour its high luminosity.

We have already learned that the true interpretation of the green colour produced by mixing yellow and blue together is that the blue absorbs the red and yellow reflected by the yellow; while the yellow absorbs the blue and violet reflected by the blue, leaving only the green rays *unabsorbed* to produce the result.

Yellow, when mixed with black or grey, produces *shades* of olive or citrine. Beautiful shades of olive can be dyed by simply employing two colours, i.e. an aniline grey and a yellow, such as naphthol yellow, tetraphenine, or tartrazine yellows. This is an instructive dyeing experiment, as the shades produced appear to be much greener than what is usually expected from the combination of a grey and a yellow.

§ 60. Blue

As blues vary greatly in tone, from greenish-blues to reddish-blues, it is somewhat difficult to assign accurately the exact position on the spectrum of a typical blue.

A beautiful greenish-blue, which is termed cyan blue, is found about the fixed line F on the spectrum; while a pure azure blue lies between the lines F and G (i.e. F$\frac{1}{2}$, G)

(see Fig. 7). At the line G the blue is of a strong violet hue.

Blue is a primary colour of the Young-Helmholtz theory as well as the practical (Brewster) theory. Genuine ultramarine made from lapis-lazuli is generally taken as the standard of a pure, normal blue, and in some of the finer aniline blues, such as victoria blue, night blue, and the alkali blues, 6 B, may be found a fair representative of the beautiful spectrum blue.

The various brands of blue now at the command of the dyer and colourist are almost unlimited since the introduction of the coal-tar colours ; but, before the aniline blues were known, the dyer depended solely on a few dyes such as indigo, woad, and Prussian blue.

There are several beautiful greenish-blues, derivations of aniline, which are much used for dyeing bright greens, peacock blues, etc. Owing to their free transmission of the pure green rays and the absorption of the red and orange in their spectra, they produce, by admixture with yellow, very luminous greens. Disulphine B, turquoise, methyl blue, cyanine, and patent blues and others may be given as examples of pure greenish-blues. Such look well in artificial light, as they keep their clear blue appearance, and do not become dull and flat like the azure blues.

In commerce the various brands of blues are designated by letters such as B, 2 B, etc., up to 6 B, which is the finest and purest tone of blue made, while the reddish-blues are characterised by the letters R, 2 R, etc., according to their degree of redness of tone.

In reference to the aniline blues and other colours it may be remarked that those which are sometimes termed the " 1st Kettle " are the best and purest products, while those of the 2nd or 3rd Kettle are not so pure, containing as they do more or less of the dissolved impurities.

Indigo blue is often mentioned as one of the seven fundamental colours of the spectrum lying between the green and blue about the line F, but this colour term is now falling into disuse, as no colour corresponding exactly to indigo is present in the solar spectrum. It is more correctly termed cyan blue instead of indigo.

Many blues of a greenish cast, such as disulphine B, alizarine, delphinol, patent blue, cyanine, and cyanol, are very useful dyes to the calico printer and dyer, not only on account of their dyeing level shades, but because they mix readily with other colours to produce useful compound shades. They are much used for giving fine tones of olive, old gold, citrine, russet, etc., with red and orange.

Such blues as we have already seen (Plate III., Nos. 1 and 2) are the best for producing clear and brilliant tones of green by admixture with yellow. This is owing to the absence of a red or violet cast.

If a blue shows a strong tendency to transmit the red rays of the spectrum, it is possible to combine it with a yellow, and produce, not a green, but a dull red or claret colour.

Take a solution of litmus, for example, which is a blue colour, transmitting the red rays more readily than the green and blue. By viewing a moderately deep blue solution of litmus through a yellow-tinted glass or film, we do not get a green as might be expected, but a purply-red colour.

§ 61. A fairly good blue can be made by combining green and violet together; such compound blues are sometimes known as "indigo substitutes" (see also § 33). The formation of this compound blue can readily be understood by resorting again to the simple chromatic circle method of examination.

Take, for example, the two dyestuffs, malachite green and methyl violet, which when combined in suitable proportion

give a very good blue (see the dyed pattern No. 4 at end of the book).

Fig. 33, No. 1, represents the chromatic analysis of the colour given by malachite green and shows the absorption of the red, orange, and violet rays, with transmission of yellow, yellow-green, green, blue, and cyan blue.

No. 2 shows the absorption of methyl violet, i.e. the orange, yellow, and yellow-green rays, while the red, and from the green to the violet, are all freely transmitted.

When those two dyestuffs are combined as shown in

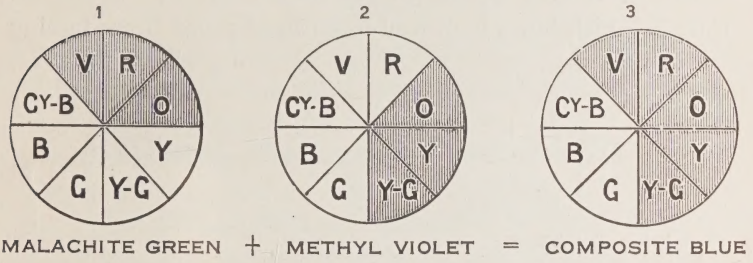


FIG. 33.—Simple chromatic circle showing the formation of a blue by the combination of a malachite green and methyl violet.

No. 3 the only coloured rays which are not absorbed are the cyan blue, blue, and green. These combine on the retina of the eye to give the sensation of the blue ; hence the origin of the blue colour by the mixture of green and violet. This may also be represented by the absorption curve, as in Fig. 34, instead of the chromatic circle. If we examine such a composite blue with the spectroscope, we shall find the brightest part of the spectrum, i.e. orange-red, orange, yellow, and yellow-green, is more or less absorbed, while the green and blue of the spectrum are freely transmitted.

The benzaldehyde greens, like victoria and malachite, transmit a certain amount of red which gives to the compound blue a violet cast : but if a purer green be employed,

showing total absorption in the red, a much purer blue will be obtained by admixture.

(A) represents the absorption spectrum of malachite green, showing strong absorption in the orange-red at C. (B) is spectrum of methyl violet, showing strongest absorption in the yellow at D. (C) gives the absorption curve of a composite blue (A and B mixed), showing the transmission only of a green and blue, with a little extreme red (see the dyed specimen No. 4 at the end of the book).

Blues change greatly in appearance in an artificial light, especially if they belong to the deep azure or violet cast. Pure greenish-blues look well in gaslight ; but those having

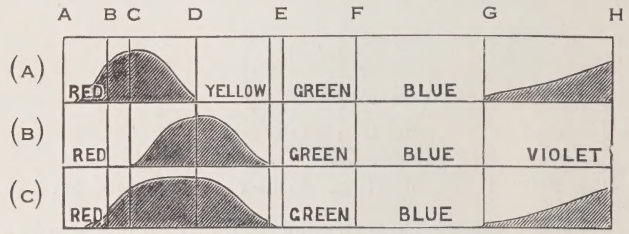


FIG. 34.—Absorption spectra of (A) malachite green, (B) methyl violet, (C) composite blue produced by combination of (A) and (B).

the slightest tendency towards a violet hue appear much redder and duller. Deep navy blues appear almost blacks in ordinary gaslight, from the deficiency of blue rays in that illuminant. For the aspect and behaviour of the various colours under artificial lights, the reader may consult the companion volume on *Colour Matching on Textiles*.

When red and blue are combined, violet is produced, as we have already seen in No. 6 of Plate III. and also in the frontispiece. A scarlet red does not produce a good violet ; the red must tend to the bluish or crimson hue. Blues, when mixed with proportions of grey or black, produce various shades of bluish-greys or slates, and, when reduced with white, give delicate tints of pale blue.

CHAPTER VII

SECONDARY COLOURS—ORANGE—GREEN—VIOLET—NOMENCLATURE OF VIOLET AND PURPLE GROUP—VIOLET FROM RHODAMINE PINK AND WOOL GREEN—PURPLE—TINTS AND SHADES OF VIOLET—CHANGES IN ARTIFICIAL LIGHT.

§ 62. Orange

ORANGE, being composed of red and yellow, constitutes one of the secondary colours of the Brewster theory. On the spectrum it occupies a place between these two colours, and is somewhat difficult to locate with certainty, as the orange merges into the red on the one hand and the yellow on the other. The position assigned to normal orange is slightly beyond the line D, towards the C line (see Fig. 7). A good standard of a full orange colour is seen in the skin of a ripe orange.

For long the dyer and calico printer made their orange colours by the proper mixture of red and yellow, but this is unnecessary now, as the beautiful series of aniline azo oranges, purer than those obtained by admixture, are at his disposal. In making a good orange by admixture, it has already been pointed out (Nos. 3 and 4, Plate III.) that the red should tend to be more of a scarlet than a crimson red, and the yellow should not have a greenish cast ; otherwise a poor quality of orange is obtained by their combination. Many beautiful, direct dyeing colours, basic, acid, and azo-orange dyes are employed along with the aniline reds, blues, and greens to produce in dyeing a wide variety of useful compound shades of russet, olive, sage, old gold, citrine,

etc. A few of these compound shades are considered under the tertiary colours.

It is an interesting experiment to observe with the pocket spectroscope the formation of an orange by the addition of a little red to a yellow. A solution of naphthol yellow gives a beautiful bright yellow, which, on examination with the spectroscope, is seen to consist of red, orange, yellow, yellow-green, and green rays. If a few drops of a red solution—say 2 R scarlet or roccelline—be added to the yellow, it will be observed that the absorption band has greatly increased; the green rays have been absorbed, and the band extends from the violet to the yellow-green. If a few drops more of the red solution be added, on viewing again with the spectroscope, the yellow-green will now be found absorbed, each little addition of red gradually increasing the absorption of green and yellow-green, until only red, orange, and yellow are transmitted, which go to produce an orange. If the addition of red be continued, the yellow will also be absorbed until the solution transmits only red and orange rays, which give the sensation of a scarlet red.

The formation of an orange, as we have described by the gradual addition of a red to a yellow, may be illustrated by the foregoing diagram, Fig. 35, each curve representing the addition of a little red, and showing the gradual increase of the absorption band. Spectrum (A) represents the absorption of naphthol yellow, (B) shows increased absorption on addition of a little red, (C) shows the absorption curve of a full orange colour by admixture of red and yellow, transmitting red, orange, and yellow; while curve (D) shows an excess of red added to produce a scarlet colour, transmitting only the red and orange rays from A to C.

Orange, when reduced into tints, gives a soft series of salmon, amber, and cream colours, generally termed buffs; while, with black or grey, it produces terra-cottas, brown,

and russet shades (see dyed patterns Nos. 6 and 10 at end of book).

§ 63. **Green**

The position of pure green on the spectrum is at the two E lines, and extending for a short space on either side of them (see Fig. 7). Thus, if the spectrum from A line in extreme red to H in extreme violet be divided into 1,000 parts, the two lines at E will be found to occupy a position numbering from 638 to 664. According to Prof. Rood, a full green begins at 595 and ends about 682, where the blue-green begins ; so that the position of a good green may be

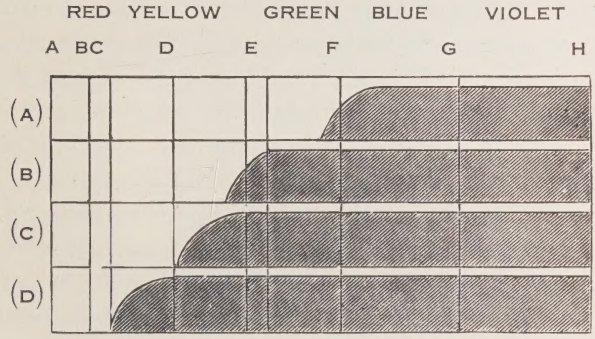


FIG. 35.—Showing the gradual increase in absorption of the spectrum by adding red to yellow to produce orange. (A) represents absorption spectrum of any of the aniline yellow dyes. (B) with slight addition of red. (C) a full orange colour by admixture of yellow and red. (D) represents the absorption of the spectrum where excess of red has been added to the yellow, producing a scarlet, the red and orange rays being alone transmitted.

said to lie at the E lines (see Fig. 7, p. 20). In the Young-Helmholtz theory of colour sensation green takes the position of a primary colour ; but in the practical theory employed by the dyer and colour mixer it occupies the position of a secondary colour, being a mixture of yellow and blue.

If blue and yellow lights be combined, white light is produced, and, as we have already learned (§ 59), yellow in the true scientific sense is not a primary colour, but is formed by combining red and green lights.

A very good example of a pure green may be found in emerald green with a trace of lemon yellow. In dyeing a pure, bright green is obtained with some of the aniline greenish-blues and naphthol yellow. Three parts quinoline yellow and two parts victoria or acid green dye a beautifully bright tone of emerald green. For a full, deep acid green see dyed pattern No. 2 at end of book.

Before the introduction of coal-tar colours it was difficult for the textile colourist to produce a brilliant green, for, strange to say, though green is such a universal colour in nature, we have no natural green dyes. The green colouring matter of leaves and plants, i.e. chlorophyll, though it gives a beautiful green colour in alcoholic solution, cannot be employed as a dyestuff. Since the introduction of the aniline greens, yellows, and blues the dyer has a wide variety of colours at his disposal, ranging from yellow-greens on the one hand to blue-greens, turquoise, cyanine, and peacock blues on the other. In commerce the various brands are sometimes designated by a J or a G, i.e. (Fr.), Jaune = yellow shade, as sulpho-green, J ; acid green, JJ ; or (Ger.), Gelb = yellow, as wool green, G, acid green, 2 G, etc.

The production of a green by the combination of a blue and yellow affords a very interesting and instructive example of a selective absorption, which always arises when two different colours are combined. The true interpretation of this formation of green by mixing blue and yellow we have already fully considered in Chapter IV., § 29. By combining the various aniline greens with orange G, Bismarck brown, fustine, or similar red-brown colours, pleasing shades of russet, bronze, olive, citrine, etc., are produced.

Greens, when reduced to form tints, give pale tones of sea green, pea green, etc. ; while, with the addition of grey or black, various shades of moss green, sage, and myrtle are produced.

§ 64. Violet

The violet-coloured rays, being the most refrangible of all the visible rays of the spectrum, are found at the extreme end of the spectrum, and farthest away from red. If the spectrum be divided into 1,000 parts, starting from extreme red, 0, to extreme violet, 1,000, as shown in Fig. 7, we find that the colour generally termed violet commences very near 800 and extends to 1,000, which is the fixed dark line H.

Violet is a secondary colour in the Brewster or practical colour theory, as it is compounded of red and blue ; but in the true theory, of Young and Helmholtz, it is regarded more as a primary colour. The sensation of violet, though really a primary and homogeneous colour in the spectrum, is produced by the red and the blue colour nerves being excited, so that the sensation is itself a compound one.

Before the introduction of the beautiful aniline violets, such as the Hofmann and methyl violets, it was impossible to produce by admixture anything like a good, pure violet. There were no permanent colours or pigments to represent a good, full violet : the nearest approach that could be made was by mixing together ultramarine blue with a little madder pink. The violet of the spectrum, though neither luminous nor brilliant—its luminosity being only 13, compared with red = 1,000, or orange-yellow = 7,000 (see p. 71)—possesses, nevertheless, the greatest amount of chemical activity or actinic power. The chemical power decreases as the colours approach the red end of the spectrum, where there is an absence of actinic rays. It has been shown also that this same mysterious chemical action present in the violet rays

is the cause of the fading or bleaching of dyed colours on exposure to light. The nearest representation of a full, saturated tone of violet like that of the spectrum is found in some of the pure bluish aniline violets, which are the ethyl and methyl derivatives of rosaniline. Formyl violet, 4 B, also gives a good representation of a violet colour.

§ 65. Between a blue-violet on the one hand and a red-violet or a purple on the other, are a great number of intermediate tones all merging into each other and it is often difficult to decide when a hue of violet may be called a purple, or a mauve, or a dahlia, as they all merge so closely into each other.

No less than some twenty different hues of violet, or purples, lying between red and blue have been named by Mr. R. Ridgway, an American colourist. He describes them as follows :

1. Prune.
2. Dahlia.
3. Auricula.
4. Plum.
5. Pansy.
6. Indian purple.
7. Royal purple.
8. Aster.
9. Maroon.
10. Violet.
11. Phlox.
12. Pomegranate.
13. Mauve.
14. Magenta.
15. Wine purple.
16. Lavender.
17. Solferino.
18. Heliotrope.
19. Lilac.
20. Rose.

Even with skilled dyers and colourists there is a wide difference of opinion regarding the true tone of a violet ; but, in fact, the same might also be said of a blue, a green, and a red. The ideal standard of one colourist is often not that of another.

If we wish to produce a violet by admixture of blue and red, it must be remembered that the blue must tend towards a violet cast, and the red towards a bluish-red or crimson. Vermilion and cobalt blue, for example, or scarlet 2 R and cyanine blue, when combined, produce very poor, dull

violets, owing to the orange being present in the reds, and green in the blues.

This we have already pointed out in Plate III., Nos. 5 and 6, § 52. If, however, we take a blue inclined to violet, such as ultramarine or the azure-blues, and combine them with a bluish-red like madder lake or acid magenta, then a purer and richer violet is the result.

§ 66. An interesting example of a violet produced by admixture is that obtained by combining magenta, or rhodamine pink, with wool green, or any other aniline greenish-blue, which absorbs the red and orange rays.

The formation of this violet is interesting from the colourist's and spectroscopist's point of view, as it illustrates clearly the phenomenon of colour absorption ; and also the

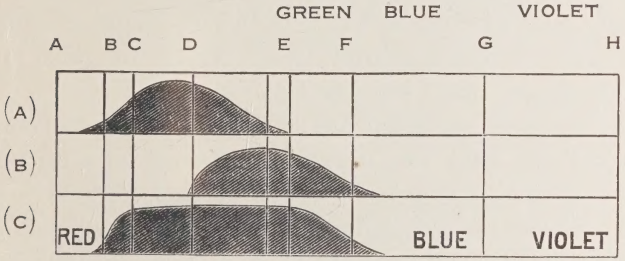


FIG. 36.—This represents the absorption spectra of (A) wool green and (B) rhodamine pink, which, when combined, produce a violet showing the absorption spectrum of (C).

fact that the colour of a mixture always consists of those rays which are transmitted freely by the component colours.

Thus (A) of Fig. 36 represents the absorption curve of a greenish-blue, termed wool green S, showing its absorption of the cherry-red at line C, and extending through orange towards yellow at line D, where absorption gradually decreases towards the E lines in green. The colour of wool green, therefore, consists of the extreme red rays and the green, blue, and violet.

The beautiful pink dyestuff rhodamine or rosazeine in (B) shows absorption in the brightest part of the spectrum, i.e. yellow, yellow-green, and green, while red, orange, blue, and violet are freely transmitted. When these two dyestuffs are combined, as at (C), it will be observed that only the extreme red, the blue, and violet are transmitted, all the other coloured rays being absorbed in the combination. Thus the absorption spectrum (C) represents that of a violet compounded of wool green and rhodamine pink. If a green dye be used that absorbs all the red rays, a still purer violet will be obtained. The object of the green colouring matter is simply to absorb the red end of the spectrum of the rhodamine, which leaves only the violet end to be transmitted.

In this case the effect produced is exactly the opposite of that mentioned in Chapter VI., § 55, where orange is added to rhodamine to form a scarlet, by absorbing the violet end of the rhodamine spectrum (see Fig. 31).

But no matter how violets are produced by the admixture of two colours, they can never be obtained so pure and saturated as the homogeneous or self colours, derived from aniline. Violets are generally designated as blue-violets or red-violets by attaching the letters B or R to their names. Thus methyl violet B is a bluish-violet ; 2 B a bluer violet ; 4 B a still bluer violet ; while fast acid violet 10 B is indeed a blue with a tinge of violet.

In the same way R represents the tendency towards red, R violet being a slightly reddish tone ; while a 3 or 4 R violet is a purple, in which the red predominates.

§ 67. Between a violet where blue predominates and a purple in which the red predominates is an intermediate hue, termed mauve, being somewhat redder than violet, but bluer than purple. The term purple is itself often used instead of violet, but this is confusing, as the true purple

is much redder than violet ; it can be fairly represented by combining magenta and mauve. The imperial, or Tyrian, purple of the ancients, which was derived from the shell-fish murex, or *purpura* (hence our word purple), was considerably redder in hue than our present-day notion of purple.

As much confusion often arises in naming the various hues in this group of colours, we give here the usual colour terms intermediate between blue and red.

Azure-blue.	Purple.
Purplish ultramarine.	Wine purple.
Violet.	Crimson.
Mauve.	Magenta.
Dahlia.	Red.

§ 68. Tints of violet are known as lavender hues, which are really very light violets of a bluish cast. The tints of reddish-violets are termed lilacs, heliotropes, or peach-blossom. Violet, when mixed with grey or black, gives shades of plum and slate.

§ 69. Colours belonging to the violet class alter greatly in appearance in artificial light. As the ordinary illuminants, like coal gas, oil lamp, or candle-lights, are poor in blue and violet rays, all violet colours, when viewed in such lights, appear much redder, from the fact that a large proportion of their blue and violet light is quenched, leaving the red in predominance. Hence deep tones of violet appear almost blacks in gaslight, and the lighter tints become changed to pinks and magentas.

CHAPTER VIII

TERTIARY SHADES

BROKEN HUES—MAROONS—BROWNS—CITRINES AND OLIVES —ABSORPTION SPECTRA OF TERTIARY SHADES—DYED PATTERNS.

§ 70. We come now to consider the large class of shades which contain grey or black in their composition. They may be considered as simply the primary and secondary colours dulled, or what is termed "saddened," with a proportion of grey. We have already explained (Chapter V., § 45) the true constitution of these so-called tertiaries, and shown them to be dulled tones of red, orange, yellow, green-blue, and violet. The principal "broken hues," as they are sometimes termed, may be classed as follows:

When Mixed with Black—

(1)	Red	becomes	maroon.
(2)	Orange	,,	russet.
(3)	Orange-yellow	,,	brown.
(4)	Yellow	,,	citrine.
(5)	Yellowish-green	,,	olive.
(6)	Green	,,	sage.
(7)	Bluish-green	,,	blue-sage or myrtle.
(8)	Blue	,,	slate.
(9)	Violet	,,	auricula.
(10)	Purple	,,	plum.

These broken hues, with their corresponding complementaries or harmonising shades, are given in Fig. 30.

It would be a tedious as well as a profitless task to enter minutely into the description of the various methods of producing the many tertiary shades, but we shall choose for our

study a few simple and characteristic examples, which will show sufficiently the nature of all the shades belonging to this large group.

§ 71. In mixing colours to produce soft tertiary shades it is better not to employ clear and decided primary colours, as the slightest excess of any one produces a great alteration in the mixed shade, which causes the colour to be easily put off its desired hue. In practice it is better to employ dull, sad colours when mixing to form delicate compound shades. A slight excess of one or other of the colour ingredients does not then produce such a marked result as when the colours used are bright. Shades, mixed in this way, are easier matched and kept on the proper standard. For example, it is better to employ say metanil yellow, carmoisine WS, and indigo carmine than the pure and brilliant primaries, red, yellow, and blue.

There are now at the command of the dyer and textile colourist a great many dyestuffs having beautiful, soft shades, which are useful for colour mixing and producing all kinds of shades by admixture, instead of destroying the luminosity and purity of the more expensive primary dyes by combining them together.

Another reason why bright colours had better not be employed for making soft tertiary shades is the fact that a soft, drab shade made by combining bright colours is more liable to show abnormal changes in artificial light. Such shades are often like optical see-saws, changing in aspect with every slight change in the quality of the light.

Clear bright blues, which show decided absorption of the red part of the spectrum are never very satisfactory in producing stable tertiary shades. Such shades become greener in artificial light, and even change in appearance in different qualities of daylight.

Shades of this kind have another interesting, but often rather puzzling quality, of appearing differently to different observers, particularly if there is a considerable range in the ages of the observers.

As the human eye gets older, the lens acquires a yellowish tinge, and this slight yellowness tends to upset the normal value of the colour appearance.

It is as if one viewed the shades through a yellow-tinted glass, and the blue constituent at once becomes more predominant. To young eyes there is no such change, but to those of about fifty years of age and upwards the difference is most pronounced, a young observer seeing the shade one way and an older and more experienced observer seeing it quite different. Such shades are always perplexing, and should be avoided as much as possible.

In colour mixing and dyeing it is desirable to have as few colour constituents as possible to produce the desired result, as a variety of colouring matters in a certain shade only produces complexity when the shade requires to be matched or altered to a desired standard. No more than three or four colours are necessary to give any shade that is wanted.

All the various tertiary shades merge imperceptibly from the one hue into the other, and hence give rise to innumerable combinations of hue, tint, and shade, which are often as difficult to match accurately as they are to describe or to name.

We shall now proceed to consider briefly the nature of a few of the tertiary shades.

§ 72. *Maroons.*—Pleasing shades of red ranging from a claret and darkening down to a maroon, a puce, or red-black are obtained by combining red with varying proportions of black or with its complementary green. If the reds have an

orange tone, i.e., scarlets, various shades of chocolate, terra-cotta, and red-browns are obtained.

A fine series of darkened reds can be made from fast red or roccelline, or any of the other aniline reds and victoria or malachite green. Every addition of green to the red produces the same effect as an addition of black.

When the red and the green are sufficiently strong there is a complete absorption of all rays, and a black is the result. For an illustration of this see Fig. 15.

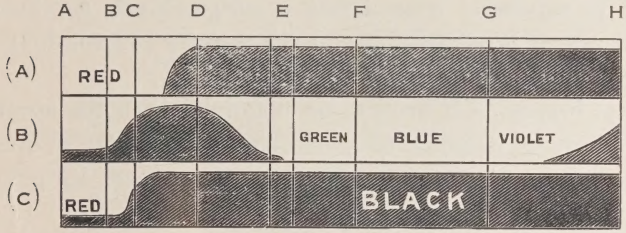


FIG. 37.—Diagram showing how fast red (A) and an aniline green (B) such as malachite, when combined, produce a claret or maroon, namely, a red of low luminosity, all the other rays being absorbed. The shaded parts represent absorption of light.

To show that a claret, or such shades as are termed cerise, grenadine, garnet, etc., deepening down to a maroon, produced by combining red with green, are simply darkened reds, we may examine the combined spectra of the two colours. In Fig. 37, for example, (A) represents the absorption spectra of fast red or roccelline, and (B) that of an aniline bluish-green, such as malachite or other benzaldehyde greens. When these two colours are dyed together or mixed in calico printing, the result represented in spectrum (C) is produced. All the colours of the spectrum are absorbed or quenched, with the exception of the extreme red, producing a red of very low luminosity, and darkened in a manner similar to that obtained by adding some black. The shaded

portions on the diagram represent, as in all the others, the absorption of colour at those parts of the spectrum.

By making a habit of analysing the formation of shades in this graphic manner, the student may clearly understand the optical structure of all mixed colours.

In a maroon, plum, or claret colour the red is in excess; but if, while mixing the red and green together, the latter be used in excess, then dull shades of green-greys or sages, deepening to greenish-blacks, are produced.

The terms plum, maroon, and puce are generally understood to represent respectively a purply-black, a crimson-black, and a brownish-maroon. The term puce is literally "flea colour," from (Fr.) *puce*, a flea.

§ 73. *Browns.*—If browns be examined with the spectroscope they will be found to consist simply of scarlet, or orange greatly diminished in luminosity. They are, in reality, degraded or "broken" hues of orange.

As already shown in Chapter V., § 45, the formula of russet, when analysed, shows it to be a red-grey. Orange and violet, when combined, produce russet or red-brown, thus:

Orange, as we know, is composed of red + yellow.
Violet ,, ,, red + blue.

So that the symbol for russet would be—using their initial letters—$R_2\ Y_1\ B_1$. When we bear in mind that red + yellow + blue produce grey we find that russet + red = grey. But the red should be of the orange hue, or a scarlet to produce a good russet shade. As the scarlet becomes more of an orange, the shade produced on its mixture with grey becomes more of a yellow-brown, until it merges into a yellow-grey or citrine. See the rich shade of brown, No. 6, of yellow-brown, No. 10, and of citrine or olive, No. 5, in the dyed Pattern Plates at the end of the book.

The great variety of such shades often perplexes the dyer and the colourist in their matching operations.

Beautiful shades of walnut and sealskin browns ranging to brownish-olives can be made from combinations of carmoisine WS, acid orange, and lissamine green B (or wool green S).

For example, a fine, rich brown is dyed with

2 parts acid orange.
1 part carmoisine WS.
½ part lissamine green B.

By varying the proportions of these ingredients three different classes of shades are produced, i.e. those having

A predominance of	red	giving	plum tones ;
,,	orange	,,	brown tones ;
,,	green	,,	olive tones.

Thus a fine yellow-olive is dyed with

5 parts orange,
¼ part red, or carmoisine WS.,
1 part green,

and a green-olive with

4 parts orange,
1 part green.

By employing fast yellow instead of orange a beautiful series of neutral greys are obtained. If in such combinations red or orange predominate, a brown is the result ; if yellow be in excess, a citrine or olive is produced ; and if blue predominates, a slate or myrtle green.

Thus in the dyed patterns in the appendix it is seen that from metanil yellow Y, indigo carmine X, carmoisine WS, can be produced shades of all kinds ranging from citrines and browns to sages and pure greys. No. 5, Plate II., is a citrine shade. If the red or magenta be in excess, a brown is produced as at No. 6, and if orange be in excess, a shade of old gold is the result as at No. 10. If green be predominant then

a sage is produced as shown in pattern 11. If these three aforementioned dyestuffs be combined in suitable proportions, a beautiful series of pure greys, ranging from a light to a dark grey, can be obtained. These are seen in patterns Nos. 7, 8, and 9.

Rich shades of russet are made by combining methyl violet 3 B and orange. This is an interesting example of colour absorption, as it shows clearly our case in point, i.e. that russet or brown is simply a dull or degraded orange-red.

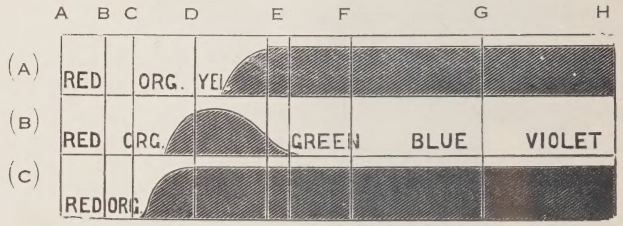


FIG. 38.—Showing the production of a russet shade by the combination of orange 2 (A), and methyl violet (B) ; (A) and (B), when combined, produce blackness from violet to orange yellow C½ D, thus giving a broken hue of orange-red, i.e. russet, spectrum (C).

This may be illustrated in a simple manner by using the absorption curves of these two colours and combining them together, as at (C), Fig. 38, when an orange-red with all the other rays of the spectrum absorbed is formed. This gives an orange-red much degraded with black, or, in other words, a russet or brown shade.

In Fig. 38 (A) represents the absorption spectrum of orange 2, which shows the absorption of all coloured rays from violet at H to the yellow-green at D½ E. The red, orange, and yellow, being freely transmitted, produce its orange colour.

(B) gives the absorption of methyl violet, showing it to be

in the locality of orange-yellow, yellow at D, and extending as far as the E lines in green. The green-blue, blue, and violet are freely transmitted, along with the red and orange rays from A to C½ D.

When these two dyes are combined, the result obtained is shown at (C), where all the rays are absorbed from H in violet to C½ D in orange-yellow, producing a large amount of grey, combined with red and orange. This constitutes the shade of russet produced by combining methyl violet and orange (see also Fig. 39).

Fine shades of russet can be dyed direct from the homogeneous brown dyes, such as vesuvine or Bismarck brown, fast brown, naphthylamine brown, etc.

Russets, when reduced into light tints, give various shades of brown drab, buff, fawn, light amber, and the innumerable class of shades termed warm mode hues.

§ 74. *Citrines and Olives.*—As already shown in § 45, the class of shades known as olives and citrines are composed of green and orange, and are simply yellows and yellow-greens saddened with varying proportions of grey. Beautiful shades of olive may be obtained by combining naphthol yellow, wool green, and orange ; or indeed any of the three dyestuffs employed to make the other tertiary shades, only *the yellow must be the predominating hue* (see Fig. 40). When a pure yellow is saddened down with a neutral grey, there is produced a shade of olive which is much greener in hue than what we would generally expect. Indeed it is often difficult to imagine such a shade produced without the addition of a little green. For example, if naphthol yellow be dyed along with a pure neutral tint of grey, such as nigrosine, a shade of olive is obtained having a decidedly green hue, similar to that dyed with yellow, orange, and a green or blue. To those who have not observed this, it is well worth performing the experiment. We have already

learned that a reddish-yellow combined with a reddish-blue produces an olive or citrine shade (see dyed pattern No. 5 at end ; also Fig. 1, Plate III).

§ 75. *Absorption Spectra of Tertiary Shades.*—The following Figs. (39, 40, 41), might be taken to represent three typical absorption spectra of tertiary shades, showing the predominating effect of one of the constituents :

Fig. 39 (No. 1) is the absorption spectrum of a brown obtained by combining an orange and a blue together.

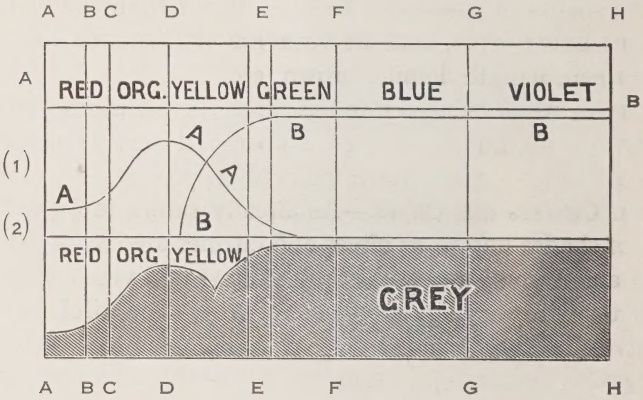


FIG. 39.—Showing the construction of the absorption spectrum of a shade of russet composed of orange G and victoria blue. Shaded part, spectrum 2, represents absorption of light.

The line marked A, A, A, is the absorption curve of an aniline blue resembling victoria blue, and showing absorption in the red, orange, and greatest in the yellow and yellow-green, D and D½ E.

The other line, B, B, B, represents the absorption curve of orange G, showing total absorption of the violet, blue, and green from fixed lines H to E in green. Absorption gradually decreases towards the D line in yellow.

The line drawn along the spectrum marked A, B,

represents the line of total absorption of coloured rays, and where the curves reach up to this line there is total absorption, or blackness in the spectrum.

The spectrum No. 2 is the same as No. 1 above it, but shows the shaded portion of the spectrum where absorption takes place. This shows the shade of russet composed of orange G and aniline blue to be simply red, orange and yellow reflected in small quantity, and mixed with a large proportion of grey, due to the absorption of the coloured rays—or, in other words, a broken hue of orange-red. It will now be readily seen that the very same shade could also

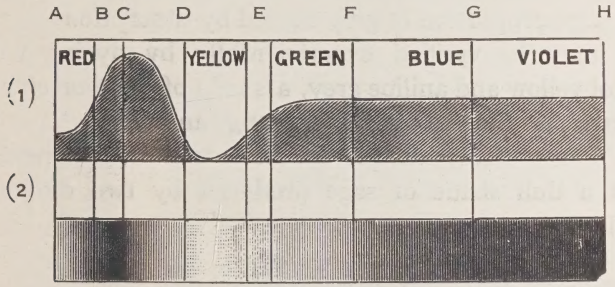


FIG. 40.—Representation of absorption spectrum of olive made with orange and lissamine green B, the green being in excess. The absorption curve in the red is due to the green, and that extending from the green to the violet is due to the orange. (Shaded portions represent absorption).

be obtained be simply adding to an orange colour a certain amount of grey or black. The dyed patterns, for example, Nos. 7, 8, and 9 are fine shades of grey produced by the combination of red, yellow, and blue.[1] If the red and yellow be in excess, a brown is produced as shown at No. 6. A greater excess of yellow gives the "old gold" shade at No. 10; while if the green be in excess the sage, No. 11, is produced.

[1] To produce such neutral greys, great care is required in the balancing of proportions of the constituent dyes.

§ 76. Fig. 40 gives a representation of the spectrum of an olive produced by combining lissamine green B and orange, the green being in excess.

The strong absorption in the red and orange from lines B to D is due to the wool green ; while the absorption curve extending from the E lines in green to the violet is due to the orange constituent. When both are combined it will be observed in diagram 2 that the only rays allowed to pass freely are the yellow rays with a considerable quantity of green, all the others being more or less absorbed, especially the red and orange. This shows that an olive is simply a dulled or broken yellow-green, i.e. a yellow-green mixed with a large proportion of grey caused by absorption.

This may be verified experimentally by dyeing with naphthol yellow and aniline grey, a shade of olive or citrine which matches the one dyed with orange and green.

§ 77 For a final example we may take an interesting case of a dull shade of sage produced by two different methods, i.e. :

1st, by combining = naphthol yellow and methyl violet, and
2nd, ,, = naphthol yellow, lissamine green B, and a trace of red.

Both of these shades of sage were exactly similar in daylight, but, strange to say, in gaslight they presented an appearance altogether different from each other.

No. 1 shade appeared a *reddish-brown* in gaslight, while No. 2 became a *pale olive.*

In order to study the reason of this difference in behaviour let us represent their optical structures diagrammatically.

No. 1, Fig. 41, represents the absorption spectrum of the sage shade composed of naphthol yellow and methyl violet. It shows absorption of the violet and the blue (caused by the naphthol yellow), and absorption of the orange, yellow, yellow-green, and a little of that green (caused by the methyl

violet). This shows the sage colour to be compounded of the red and red-orange rays, with a proportion of the green and blue-green.

The red rays are freely transmitted, and the green rays at E and F are more or less absorbed. This explains the cause of its much redder appearance in artificial lights. Such a shade when dyed on fabrics exhibits strange dichroic properties, its deeper shades appearing much redder than its lighter tints.

Spectrum No. 2 of Fig. 41 represents that of a sage exactly matching No. 1, but composed of naphthol yellow, lissamine green B, or wool green, and a little red. It will be

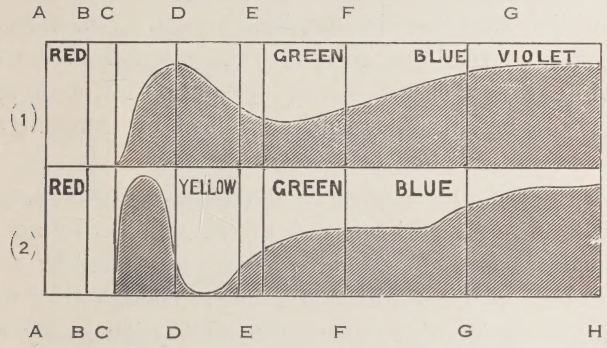


FIG. 41.—Absorption spectra of a sage green colour. No. 1 composed of naphthol yellow and methyl violet. No. 2, of naphthol yellow, wool green, and a little red. Both colours match each other in daylight, but not in gaslight. They have differently-constructed spectra.

observed that, though the two colours may closely resemble each other when dyed on wool, their absorption spectra show considerable differences. This spectrum shows strong absorption in the cherry-red, $C\frac{1}{2}$ D, while the yellow, green, and blue are more readily transmitted than in the case of No. 1. The several individual absorption lines in No. 2 may be traced to the constituent colours; thus the strong

absorption in the cherry-red is due to the wool green, that in the green and blue is owing more to the presence of the little red, while the strong absorption of cyan blue and violet G, to H, is due to the naphthol yellow. If the absorption curves of these three dyestuffs be superimposed (making the red very dilute) an absorption spectrum is obtained which corresponds exactly to that of No. 2.

It is readily seen that No. 2 colour shows a much freer transmission of the yellow, yellow-green, and blue-green rays than No. 1 ; hence these two colours, differing so widely in optical structure, can never appear identical when examined under artificial illuminants. In this case the green comes into prominence in gaslight, giving the sage shade a greener or more olive hue than its daylight aspect. No. 2 shade shows a greater tendency to reflect the green than the red rays, while No. 1 shows exactly the opposite, having a tendency to absorb the green and reflect or transmit the extreme red.

The light sky blue shown in dyed pattern No. 4, and composed of methyl violet and green, will be found on examination in gaslight to become very much redder than a similar tone of a pure, unmixed blue. Though they may both present an identical appearance in daylight, they will differ widely in hue in gaslight. The non-composite blue appears little changed, but the dyed pattern No. 4 becomes quite a delicate violet or lavender hue.

This, however, deals with the interesting study of colour appearances under artificial lights, and the causes which govern their changes in hue—a subject of great importance to dyers, which is considered specially in the companion volume on *Colour Matching on Textiles*.

§ 78. Each of the dyed specimens here appended have already been considered in their proper places throughout these pages ; but, as these references are necessarily

somewhat dispersed, it may be well to refer to them collectively.

Dyed Pattern Plate I

(The weights of dyestuffs mentioned are, in every case, for 100 lb. material.)

No. 1 is dyed with :

Carmoisine WS 3 per cent.

Carmoisine WS, when sufficiently strong, absorbs all the rays of the spectrum except red. If, therefore, it be mixed with an equally strong green, which absorbs all the red rays, then a total absorption of light, or a black, is the result, as shown in dyed specimen 3.

No. 2 is acid green G 4 per cent. This green shows no transmission of the red rays at the strength named, and must, therefore, when combined with carmoisine as above, produce the absorption of all coloured rays, or a black.

No. 3. Black produced by the combination of :

Carmoisine WS 2 per cent.
Acid green G 3 ,, ,,

This shows the total absorption of light as represented in Fig. 15, § 31.

Plate II

No. 4 is a light sky blue of a composite nature dyed with :

Malachite green 0.08 per cent.
Methyl violet 2 B 0.04 ,, ,,

As shown in Figs. 16 and 33 at § 33 and § 61, when violet and green are mixed together, it is found that the blue is the only colour common to them both, and it is therefore not absorbed. Hence the origin of such composite blues. If

the specimen here shown had been dyed much stronger, a deeper and purer tone of blue would have been obtained.

Composite blues of this nature change greatly in artificial light; and if this dyed specimen be examined in gas or electric light beside a homogeneous or unmixed blue of the same tone of colour, such as disulphine B or any similar aniline blue, it will be observed that the composite blue changes from a sky blue to a heliotrope or lavender colour, while the other blues show little change.

No. 5 is a citrine shade dyed with:

Metanil yellow Y	0.4 per cent.
Indigo carmine X	0.15 ,, ,,

We have already observed (§ 52, Chapter VI.) that a pure tone of yellow and a greenish-blue give a good green by admixture. But if the yellow or the blue tend to be of a reddish hue, then the mixture is dulled with grey, caused by the presence of the third primary (red); and, instead of a good green, a broken or saddened green is produced, i.e. a citrine or an olive.

Metanil yellow and indigo carmine are both of a reddish hue, so that, when they are combined in the dye-bath, or the colour printing paste, a saddened yellow-green or a citrine is produced, as shown in this dyed specimen.

No. 6 is a rich brown or russet dyed with:

Metanil yellow	2.1 per cent.
Carmoisine	0.15 ,, ,,
Indigo carmine	0.5 ,, ,,

We have observed in § 73 that, when the three above-mentioned dyestuffs are combined in suitable proportions, all the coloured rays are quenched or absorbed, and a pure, neutral grey is the result (see dyed specimens 7, 8, 9). But if the yellow and the carmoisine WS be in excess, we

obtain a broken tone of orange, or a brown, as here shown. If the orange be in great excess, then a clearer orange-brown is produced, as shown in dyed specimen 10.

Plate III

Nos. 7, 8, 9, are a beautiful series of greys produced by the combination, in suitable proportions, of the three practical primaries, red, yellow, and blue. No. 7 is a light neutral grey, and by increasing the proportions of dyestuffs a deeper tone of grey is produced as in No. 8, while further addition gives a dark grey, shade 9. These form an excellent series of pure, neutral greys which, unlike many similar composite greys, show little or no alteration in hue in artificial light.

They were dyed as follows:

Dyestuff.	(7) *Light.*	(8) *Mid.*	(9) *Dark.*
Metanil yellow Y .	0.01	0.045	0.09
Carmoisine WS. .	0.04	0.10	0.20
Indigo carmine X .	0.37	1.00	2.00

(The above proportions are per cent. of weight of material dyed.)

Plate IV

No. 10 is a fine shade of an orange-brown (broken tone of orange) dyed with:

Orange G	2.0 per cent.
Metanil yellow Y	0.08 ,, ,,
Indigo carmine WS	0.20 ,, ,,

It will be observed that in this tertiary shade the orange is in great predominance, so that it is simply an excess of orange + grey (see § 73).

No. 11 is a soft tertiary shade between a sage and an olive, produced by greatly diminishing the red or orange in the browns already considered, until the blue and the yellow are in the predominance. It is, therefore, in reality, a broken tone of green, or a green mixed with a large percentage of grey (see § 45, *et seq.*).

It was dyed as follows :

Metanil yellow	0.23 per cent.
Carmoisine	0.03 ,, ,,
Indigo carmine WS	0.5 ,, ,,

THE END

INDEX

A

Absorption, colour by, 7, 32
— curves, 45
— spectrum, 17, 26, 120
— — of blue, 41, 47
— — chromic chloride, 52
— — eosine, 47
— — green, 41, 46
— — indigo extract, 36
— — magenta, 44
— — malachite green, 41, 47
— — methyl violet, 41, 47
— — olive, 121
— — orange, 47, 105
— — red, 92
— — rhodamine, 55
— — ruby glass, 37, 43
— — violet, 109
— — yellow, 36, 47
Analysis of light, 12
Aristotle on colour, 59
Artificial light, colours under, 124

B

Blues, 98
Body colour, 10
Brewster theory, 59
Brightness of a colour, 71
Broken hues, 112
Browns, 116

C

Cast of a colour, 70
Chromatic circle, 81
Citrine and olive, 119
Colour a sensation, 1
— absorption, 32
— constants, 69
Colour complementary, 75, 81
— mixing, 84
— primaries, 58
— production of, 7
— scale, 74
Curves, absorption, 45
— luminosity, 43

D

Dichroism, 51, 56
Diffraction colours, 8
Dispersion colours, 8
Dyed fabrics, 57

E

Electro magnetic vibrations, 2
Emerald green, 7
Energy radiant, 1
Eosine, absorption of, 47

F

Fabrics, dichroism in, 56
Fibres, lustre of, 38
Fixed lines in spectrum, 20
Fluorescence, 8
Fraunhofer lines, 20

G

Gaslight, blues in, 102
— dichroic colours in, 122
Greens by admixture, 34, 36
— making of, 84, 105
Greys, compound, 127

H

Harmonising complementaries, 79
Heat transformed into light, 48
Hue, 69

I

Illuminated objects, 5
Interference colours, 8

L

Lambert's method of mixing, 61
Light, analysis of, 12
— wave theory of, 3
Luminosity of colours, 71

M

Magenta, 44
Maroons, 115
Mauve, 108
Maxwell colour discs, 58, 89
Metallic reflection, 10
Methyl violet, 46
Mixing colours, 84
Monochromatic light, 6

O

Objects luminous, 4
Olives, 97
Opaque bodies, colours of, 9
Optical structure, 124
Orange, 85, 103

P

Physicists' method of colour mixing, 63
Pinks, 94
Primary colours, 58
Purity of colour, 70

R

Reds, 89
Reflection, metallic, 10
Refrangibility, 14
Rhodamine, 55

S

Scale of colours, 74
Scarlets, 90
Secondary colours, 66
Selective absorption, 10
Shades, 73
Spectra, absorption, 17
Spectroscope, 23, 26
Spectrum, 12
Surface colour, 10

T

Tertiary shades, 66, 112
Tints, 72
Tones of colour, 74
Transparent bodies, 10

V

Vibration, frequency of, 4
Violets, making of, 86, 107

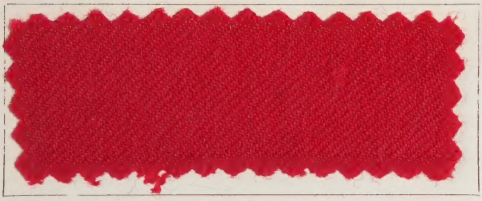
W

Warmth of black material, 49
Wave theory of light, 3

Y

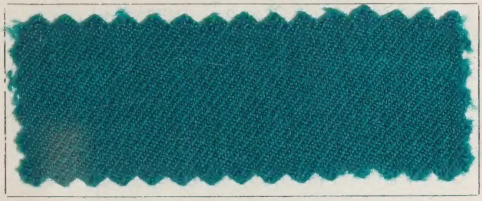
Yellows, 95
— absorption spectrum, 36
Young, Dr. Thomas, 58

PATTERN PLATE I



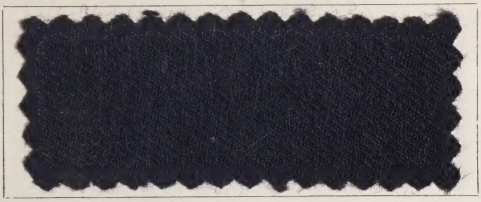
1

Carmoisine WS, 3 per cent.



2

Acid Green G, 4 per cent.

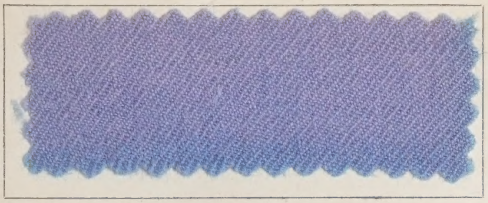


3

Carmoisine WS, 2 per cent.
Acid Green G, 3 ,,

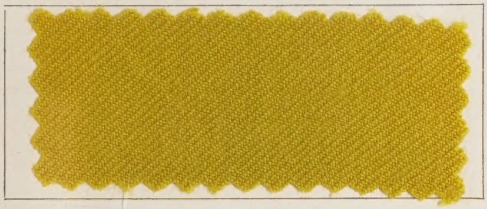
PATTERN PLATE II

(WEIGHT OF DYESTUFFS REFER TO 100 LB. MATERIAL)



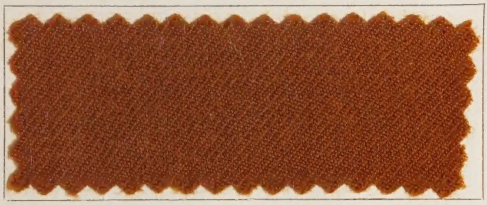
4

Light Blue, dyed with Malachite Green Crystals A (conctd.) 0.08 per cent.
Methyl Violet 2 B, 0.04 ,,



5

Citrine, from Metanil Yellow Y, 0.4 per cent.
Indigo Carmine X, 0.15 ,,



6

Rich Brown, from Metanil Yellow Y, 2.1 per cent.
Carmoisine WS, 0.15 ,,
Indigo Carmine X, 0.5 ,,

PATTERN PLATE III

(WEIGHT OF DYESTUFFS REFER TO 100 LB. MATERIAL)

7

Light Grey, dyed with Metanil Yellow Y, 0.01 per cent.
Carmoisine WS, 0.04 ,,
Indigo Carmine X, 0.37 ,,

8

Mid Grey, dyed with Metanil Yellow Y, 0.04 per cent.
Carmoisine WS, 0.10 ,,
Indigo Carmine X, 1.0 ,,

9

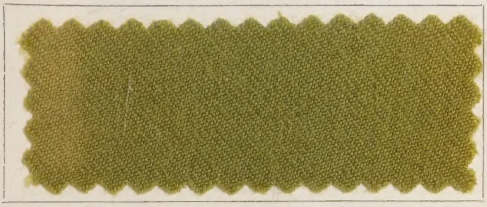
Dark Grey, dyed with Metanil Yellow Y, 0.09 per cent.
Carmoisine WS, 0.2 ,,
Indigo Carmine X, 2.0 ,,

PATTERN PLATE IV

(Weight of Dyestuffs refer to 100 lb. Material)

10

Brown, dyed with Metanil Yellow Y, 0.08 per cent.
Orange 2 G, 2.0 ,,
Indigo Carmine X, 0.2 ,,



11

Sage, dyed with Metanil Yellow Y, 0.23 per cent.
Carmoisine WS, 0.03 ,,
Indigo Carmine X, 0.5 ,,

For the dyeing of these patterns we are indebted to

Messrs. The British Dyestuffs Corporation Ltd.,

70 Spring Gardens, Manchester.

BOOKS FOR THE TEXTILE INDUSTRY

TEXTILE BLEACHING, DYEING, PRINTING & FINISHING MACHINERY

By A. J. Hall, B.Sc., F.I.C., F.C.S.

This book presents the first connected account of the essential features, both as regards construction, materials of construction, and performance, of all types of machinery for bleaching, dyeing, printing, and finishing textile fibres, yarns and fabrics.

"*It fills a gap in textile literature which had been vacant all too long. . . . The collection is unique, and will be of inestimable value to the industry. The very detailed index greatly facilitates the work of Reference.*" —Textile Mercury.

Crown 4to. With over 300 illustrations. Price 50*s.* net.

THE DYEING OF COTTON FABRICS

With a New Section on the Dyeing of Artificial Silk.

By Franklin Beech.

Third Edition, Revised and Enlarged by A. J. Hall, B.Sc., F.I.C.

CONTENTS IN BRIEF

Structure of the Cotton Fibre—Bleaching of Cotton Fabrics Prior to Dyeing—Dyeing Machinery and Dyeing Manipulations—The Principles and Practice of Cotton Dyeing—Dyeing Union (Mixed Cotton and Wool) Fabrics—Dyeing Half Silk (Cotton-Silk, Satin) Fabrics—The Dyeing of Artificial Silk—Operations following Dyeing—Testing the Colour of Dyed Fabrics—Experimental Dyeing and Comparative Dye Testing.

"*. . . in view of the great number of recipes plus the information, the book must be of great utility to all interested in the dyeing industry.*"—Cotton Factory Times.

Demy 8vo. 296 pages. 51 illustrations. Price 18*s.* net.

MODERN COTTON ECONOMICS

By Thomas Thornley.

This treatise deals entirely with the commercial and economic side of the industry. Subjects dealt with include—ordinary banking procedure, mill shares and partnerships, mill flotation, machinery making, company formation, Manchester and Liverpool Exchanges, factory laws, transport, etc., etc.

"*Very useful indeed.*"—Textile Manufacturer.

"*He has searched the whole field for possible difficulties and coped with all of them.*"—Manchester Guardian.

Demy 8vo. 362 pages. Illustrated. Price 15*s.* net.

COTTON CELLULOSE: ITS CHEMISTRY & TECHNOLOGY

By A. J. Hall, B.Sc., F.I.C.

BRIEF SYNOPSIS OF CONTENTS

Cotton and Cellulose—Raw Cotton and its Purification—Cotton and Alkalis—Cotton and Acids—Cotton and Various Reagents—Cotton and Oxidizing Agents—Cellulose and Dyes—Constitution of Cellulose—Artificial Silks—Selected Methods of Analysis.

"*To a man with experience in the cotton trade this book is of unusual interest as putting things of importance together in a thoroughly systematic way without missing essentials.*"—Engineer.

"*Every cotton technologist should buy this book.*"—Yorkshire Post.

Crown 4to. With 70 illustrations and numerous tables. Price 30*s.*

BOOKS FOR THE TEXTILE INDUSTRY

THE DYEING OF TEXTILE FIBRES

By R. S. HORSFALL, M.Sc., and L. G. LAWRIE, A.I.C.

This work by two distinguished members of the staff of the British Dyestuffs Corporation will take rank as the standard treatise on the use and application of dyes in the textile industries. Price 28*s.* net.

"The authors have produced a well-written book which is certain to be of considerable value to both dyers and students."—TEXTILE MERCURY.

"They have produced a work which simplifies a complicated range of knowledge and makes it readily available to the manufacturer and the dye-works chemist."—YORKSHIRE POST.

DYEING SILK, MIXED SILK FABRICS & ARTIFICIAL SILKS

By DR. A. GANSWINDT.

CONTENTS IN BRIEF

Silk: Further Treatment of Raw Silk—Bleaching Silk—Mechanical Operations in Silk Dyeing—Water in Silk Dyeing—Chemicals Used in Silk Dyeing—Selecting the Dyestuffs and Preparing the Baths—Basic Dyestuffs—Acid Dyestuffs—Substantive Dyestuffs—Diazotised Dyestuffs—Sulphone Dyestuffs—Mordant Dyestuffs—Sulphur Dyestuffs—Vat Dyestuffs—Natural Dyestuffs—Dyeing Silk in the Piece—Matching—Testing. TUSSAH: Scouring, Bleaching and Loading Tussah—Dyeing Tussah. WOOL-SILK: Wool-Silk and its Treatment before Dyeing—Dyeing Wool-Silk—Diochroic Effects on Wool-Silk—Half-Silk Fabrics. ARTIFICIAL SILK: Commercial Grades of Artificial Silk and their Properties—Dyeing Artificial Silk—Fabrics with Fancy Threads of Artificial Silk.

"Of great service to silk dyers . . . exceptionally well written . . . the fruit of twenty years' experience."—TEXTILE MANUFACTURER.

Demy 8vo. 228 pages. Price 12*s.* 6*d.* net.

THE CHEMISTRY OF DYESTUFFS

By DR. GEORG VON GEORGIEVICS and DR. EUG. GRANDMOUGIN.

(*Authorized English Edition.*)

BRIEF CONTENTS

Classification and General Properties of Dyes—Compounds of Dyes with Mordants—Application of Dyes—Distillation of Coal tar—Purification of Distillation Products. Intermediate Products for the Manufacture of Dyes. Benzine—Naphthalene—Anthraquinone Derivatives. Coal tar Dyes—Nitroso Dyes—Nitro Dyes—Azo Dyes—Diphenylmethane Dyes—Ketonimines—Triphenylmenthane Dyes—Xanthene Dyes—Quinoline Dyes—Anthraquinone Dyes—Hydroxyketone Dyes—Xanthone Dyes—Flavones—Naphthazarine Group—Quinoneimine Dyes—Acridine Dyes—Indigo—Vot Dyes—Sulphur Dyes—Murexide—Development of the Synthetic Dye Industry—Natural Colouring Matters—Mineral Colours—Literature of the Dye Industry.

"To be highly recommended."—CHEMICAL AGE.

"Invaluable to Dye and Colour Chemists."—TEXTILE MANUFACTURER.

Royal 8vo. 560 pages. Price 35*s.* net.

BOOKS FOR THE TEXTILE INDUSTRY

INTERMEDIATES FOR DYESTUFFS

By ALFRED DAVIDSON, B.Sc., A.I.C.

SYNOPSIS

The Chlorobenzenes and their Derivatives—The Nitrobenzenes and their Derivatives—Derivatives of Toluene—Xylene Derivatives—Naphthalene Derivatives—Phthalic Anhydride and its Derivatives—Anthracene Derivatives—Phenol Derivatives—Miscellaneous Intermediates: Carbazole—Acenaphenequinone, etc. Aliphatic Intermediates: Chloracetic acid—Acetoacetic ester—Formaldehyde—Alkylamines, etc.

"*Mr. Davidson's book marks* A REALLY IMPORTANT CONTRIBUTION TO THE LITERATURE OF DYESTUFFS CHEMISTRY AND THE DYESTUFFS INDUSTRY. . . . *If the intermediates cannot be made economically and of the requisite purity the final process of conversion into the actual finished dyestuff cannot be technically or commercially satisfactory.* THE PROBLEM OF THE MANUFACTURE OF INTERMEDIATES IS THUS THE FUNDAMENTAL ONE OF DYESTUFFS MANUFACTURE. . . . *In Mr. Davidson's Book . . . we have not been able to detect the omission or inadequate treatment of any of the important intermediates. . . . Wherever scientific or technical information supplementary to that given in the patent specification is available it is presented in Mr. Davidson's book. . . . The author has done well in preparing a special chapter on 'Phthalic Anhydride and its Derivatives,' for now that this compound is being used to an ever increasing extent as an intermediate for the production of fast anthraquinonoid colours its technical importance is growing daily.*"—THE MANCHESTER GUARDIAN COMMERCIAL.

"*The author is to be congratulated heartily.*"—F. M. ROWE.

Crown 4to. With 12 charts. Price 36*s.* net.

THE INDUSTRIAL APPLICATIONS OF COAL TAR PRODUCTS

By H. M. BUNBURY, M.Sc. (BRIS.), B.Sc. (LOND.), A.I.C. and A. DAVIDSON, B.Sc. (GLAS.).

The present work draws the attention of manufacturers, chemists, tar distillers, etc., to the full range of the materials which have been isolated from coal tar, describing their preparations, tabulating their uses and potential uses.

"*Should find a place on the shelves of all interested.*"—NATURE.

"*Has succeeded in filling a real need and bridging an obvious gap . . . the authors appear to have had close practical acquaintance with every process they describe.*"—TIMES.

Crown 4to. With 288 pages and 10 charts. Price 42*s.* net.

THE CHEMICAL TECHNOLOGY OF TEXTILE FIBRES

Their Origin, Structure, Preparation, Washing, Bleaching, Dyeing, Printing and Dressing.

By DR. GEORG VON GEORGIEVICS. *Second Edition.*

CONTENTS

CHAPTER I: The Textile Fibres. CHAPTER II: Washing, Bleaching, and Carbonising. CHAPTER III: Mordants and Mordanting. CHAPTER IV: Dyeing. CHAPTER V: Printing. CHAPTER VI: Dressing and Finishing.

Demy 8vo. 47 illustrations. 414 pages. Price 21*s.* net.

1-B25449

2/84
6488
II.LX

CONS.
SPECIAL
TP
892
P29
1927

84-B
25449

THE GETTY CENTER
LIBRARY